PB86-131216

Automatic Radio Tracking of Fish in Experimental Channels

Minnesota Univ., Minneapolis

Prepared for

Environmental Research Lab.-Duluth, MN

Nov 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-131216

EPA/600/3-85/075
November 1985

AUTOMATIC RADIO TRACKING OF FISH IN EXPERIMENTAL CHANNELS

BY:

V. B. Kuechle, K. C. Zinnel, M. J. Ross, R. A. Reichle, and D. B. Siniff

University of Minnesota
Department of Ecology and Behavioral Biology
Minneapolis, Minnesota 55455

and

University of Minnesota
Cedar Creek Bioelectronics Laboratory
Bethel, Minnesota 55005

R-805290-01-0

Project Officer

Charles Kleiner
United States Environmental Protection Agency
Ecological Research Station
Monticello, Minnesota 55362

This study was conducted in cooperation wth the
University of Minnesota, Minneapolis, Minnesota 55455

Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Duluth, Minnesota 55804

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA *(Please read Instructions on the reverse before completing)*		
1. REPORT NO. EPA/600/3-85/075	2.	3. RECIPIENT'S ACCESSION NO. PB86 131216/AS
4. TITLE AND SUBTITLE Automatic Radio Tracking of Fish in Experimental Channels		5. REPORT DATE November 1985 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) V.B. Kuechle, K.C. Zinnel, M.J. Ross, R.A. Reichle, and D.B. Siniff		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Minnesota Department of Ecology and Behavioral Biology Minneapolis, MN 55455; Cedar Creek Bioelectronics Laboratory Bethel, MN 55005		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 805290
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Duluth, MN 55804		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA-600/3
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

An automatic tracking system controlled by an RCA 1802 microprocessor was developed to locate fish in a 400 m outdoor experimental channel at the U.S. EPA Monticello Ecological Research Station. The monitoring network consisted of 12 horizontally polarized antennas spaced at 30 m intervals. The antennas were sequentially switched into a receiver, and the signal strength at each antenna was measured with the microprocessor controlling all timing, switching and measurement functions. Each fish tracked by the system was tagged with an implanted radio transmitter which had a unique frequency in the 53 MHz band. A particular fish was tracked by entering a particular radio frequency into the memory of the receiver. The microprocessor selected the antenna with the maximum signal level and printed this information along with fish number and time of day. Also, to give an estimate of data quality, a signal-to-noise index was calculated by subtracting an estimate of the background noise from the signal level obtained from the antenna closest to the fish.

During May 1979, a comprehensive tracking system performance test generated 36,000 locations on 11 walleyes, 4 open noise channels and 2 primary reference transmitters. Results indicated that the tracking system located radio-transmitters to the nearest antenna with a reliability of 98.7%. Correlation of walleye resting and movement behavior to environmental variables such as light intensity and food introduction was possible from data produced by the system.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to public	Unclassified	102
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

As understanding of the effects of waste discharges on the environment increases, it becomes more apparent that an understanding of behavioral changes by organisms exposed to such discharges is of critical importance when assessing sub-lethal toxicant effects. In order to use this technique, systems for monitoring location and movement of fish as well as water quality parameters such as temperature and toxicant level are required. This report describes the design and testing of a monitoring system developed to carry out large scale, quantitative experiments under semi-natural conditions.

This research was initiated to further develop instrumentation for tracking free ranging fish within a linear system through the use of radiotelemetry. Efforts involved were 1) implementation of an automatic tracking system to monitor instrumented fish in experimental channels and 2) the testing of both internal and external transmitter implantation procedures.

The design requirements for this contract were to: 1) locate individual rf-tagged fish to the nearest pool or riffle area, 2) be able to locate all the fish at least once every 15 minutes, 3) have a capacity for at least 30 fish, and 4) operate reliably under the environmental conditions found at the study site.

Development of the automatic fish tracking system combined existing radiotelemetry equipment with microcomputer technology for data acquisition. Other features involved were an improved antenna for reception, signal transfer and amplification, tuner lock on, signal

discrimination, timing functions and sequencing. During testing, the system was found to rapidly and precisely deliver information suitable for many types of field monitoring activities. Therefore, this technology was considered applicable to full scale field investigations where the objective was to monitor fish avoidance-preference responses.

PREFACE

The Monticello Ecological Research Station (Monticello, Minnesota), was established to gather data on complex freshwater systems under semi-natural conditions. Experimental channels have been used to study the effects of pollutant stresses on populations, communities, and ecosystems. The emphasis of research conducted at the station has been on defining responses to toxicant stress that were then used as the basis for evaluating water quality standards. One research technique was to observe the response of free ranging vertebrates to the manipulation of environmental parameters. Because of the difficulties of direct observation underwater, telemetry can be a useful tool for monitoring movement patterns of aquatic animals. In order to evaluate and measure the responses of free-ranging fish to environmental stimuli, the Monticello Ecological Research Station awarded a contract to the Cedar Creek Bioelectronics Laboratory for the development and testing of an automatic fish tracking/monitoring system.

The principal design objective in phase I was to develop a system that would be reliable under the variable and sometimes high electrical noise conditions in the vicinity of the power plant and transmission lines. Monitoring reference transmitters and open channels (noise) proved useful in determining system reliability. Other areas addressed were optimal transmitter characteristics and calibration of the system as antennas were not equally distant from the receiver/conversion device. As defined by the original proposal, phase II of the Monticello project required: (1) testing the system with rf-tagged fish in the channel for accuracy and resolution of any other problems primarily connected with

data recording; (2) determining survival and behavioral responses of study species after the attachment of rf-transmitters.

Previous underwater telemetry studies involved manual monitoring of radio frequency (rf) transmitters by hand-held receivers from shore or boat with subsequent plotting of triangulated locations on a map (Ross and Siniff 1980, Winter et al. 1978). As developed by this contract, the Monticello Remote Sensing System (MRSS) determined location by comparing signal intensity for all antennas, recording one location per fish every fifteen minutes and was accurate to the nearest pool or riffle in the channel. Moreover, the capability of the system to monitor movement patterns of instrumented fish in response to the manipulation of environmental factors was tested during May 1979. The development of this system required design effort to achieve automatic recording of position information, filtering of interference from random noise sources, and acquiring data for analysis.

During performance testing, the system was used to determine overall location selection by individual rf-tagged fish and to investigate patterns of movement behavior, especially in response to light cues. The walleye pike, Stizostedion vitreum vitreum, was selected as the test species because published data were available for comparison and because this species tolerated transmitter attachment well in preliminary studies.

ABSTRACT

An automatic tracking system controlled by an RCA 1802 microprocessor was developed to locate fish in a 400 m outdoor experimental channel at the U.S. EPA Monticello Ecological Research Station. The monitoring network consisted of 12 horizontally polarized antennas spaced at 30 m intervals. The antennas were sequentially switched into a receiver and the signal strength at each antenna was measured. The microprocessor controlled all timing, switching and measurement functions. Each fish tracked by the system was tagged with an implanted radio transmitter which had a unique frequency in the 53 MHz band. Selecting a particular fish for tracking was equivalent to requesting a particular frequency entered into the memory of the receiver. The microprocessor determined which antenna had the maximum signal level and printed this information along with fish number and time of day.

A comprehensive tracking system performance test was made generating 36,000 locations on 10 walleyes, 4 open noise channels and 2 primary reference transmitters. Results indicated that the tracking system located radio-transmitters to the nearest antenna with a reliability of 98.7%. Correlation of walleye resting and movement behavior to environmental variables such as light intensity and food introduction was possible from data produced by the system.

Transmitter effects experiments indicated that large adult white suckers were not suitable for use with radio telemetry as a test species in the experimental channels. Data from a limited sample suggested that northern pike and walleye were preferable test species.

CONTENTS

Foreword iii

Preface v

Abstract vii

Figures xi

Tables xi

Acknowledgements xii

1. Introduction 1

Study Area 2

2. Conclusions 5

3. Recommendations 7

4. Engineering Design 8

Materials 8

Methods 17

MRSS Operator's Instructions Summary 17

Detailed Software Design and Implementation 19

5. Results 29

System Verification 30

6. Discussion 40

7. References 43

8. Appendices 45

A) Glossary 45

B) Program 54

C) Operating procedures for system hardware 72

D) Effects of radio transmitters on the white sucker 88

FIGURES

Number		Page
1	Experimental Channel Schematic	14
2	Signal Strength vs Antenna Design	21
3	MRSS Hardware Configuration	24
4	Raw Data Characteristics	35
5	Data Printout	38

TABLES

Number		Page
1	Test Data Summary	42
2	Data Quality Summary	45
3	Reference Transmitter Data	47
4	X^2 Test for Accuracy of Low Signal Level Fixes	48
5	Number and Quality of Location Determinations by Antenna	50

ACKNOWLEDGEMENTS

The cooperation and assistance from the staff of the Monticello Ecological Research Laboratory is gratefully acknowledge. Dr. K. E. F. Hokanson and Jack Arthur assisted with experimental design and project administration. Roger Hermanutz assisted with the laboratory tank experiment. We are particularly grateful to Tom Henry for his help with logistics. Floyd Hennagir of the Minnesota D.N.R. and Charles Gernes of the U.S. Fish & Wildlife Service were extremely helpful in obtaining fish. Dr. Jimmy D. Winter's encouragement and critical review throughout the project is sincerely acknowledged. Dick Reichle, Ralph Schuster and Leondard Cramer, of the Cedar Creek Bioelectronics Laboratory designed, constructed and assisted with installation of the automatic tracking hardware.

This project was supported by the U.S. EPA under contract R-805-290-01-0 to the University of Minnesota.

SECTION 1

INTRODUCTION

Developmental aspects of the Monticello Remote Sensing System (MRSS) discussed in this report are: the system hardware configuration together with the software program implementation, the characteristics of MRSS in operation, and an evaluation of the data from the field testing of the system done during May, 1979. The conceptual model for the engineering design of the hardware is discussed in the materials section, while the framework for the software implementation is discussed in detail in the methods section. The results and discussion sections focus on the operational characteristics of MRSS, examining the accuracy of position information obtained with the system and also the experimental difficulties with respect to external conditions at Monticello.

A 28 day performance test using 11 walleyes, Stizostedion vitreum vitreum, with surgically implanted radio-transmitters was made in order to provide baseline data on the operation of MRSS and guidelines for interpreting the position information recorded. Manual testing of accuracy was also done to verify that both the hardware and software were operating according to specification. To continuously monitor reliability, transmitters in fixed, known locations were used as references. For the first 36 hours of operation of MRSS, there were reference transmitters at each pool (antenna #'s 2,4,6,8,10, and 12). Then the transmitters at pool #8 and #12 were attached to cement blocks and submerged in the center of the channel until May 29th, the termination of the field tests. Also monitored were 4 "open channels", i.e. frequencies without actual transmitters, but within the range of the

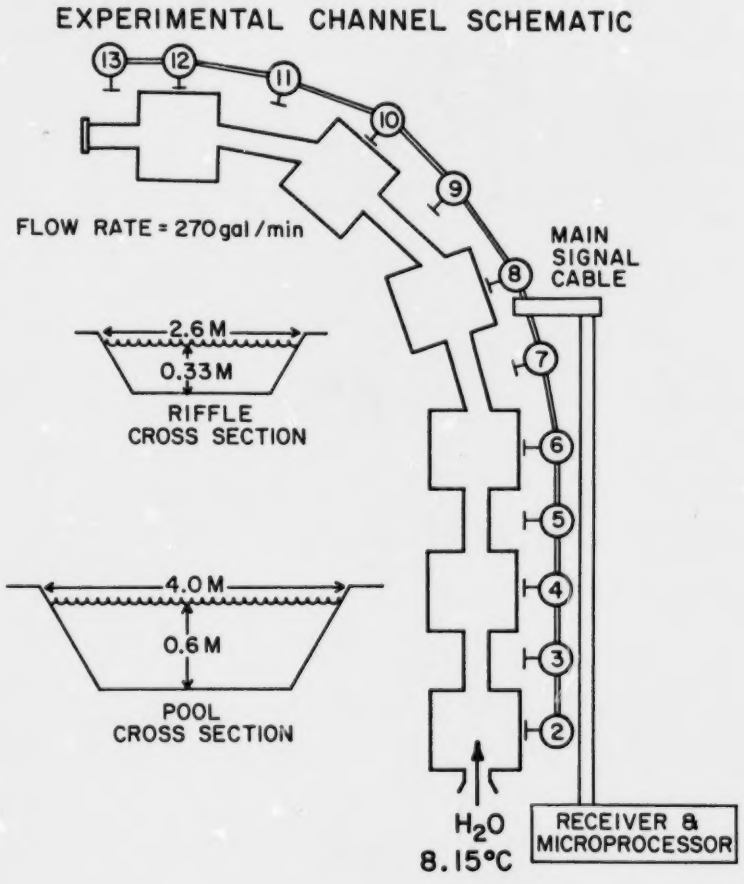
operating frequencies. These were used to determine whether interference from external electrical noise could disrupt operation of MRSS.

STUDY AREA

The Monticello field station of the National Water Quality Laboratory (Duluth, Minnesota) was designed to facilitate field studies of aquatic organisms under controlled conditions. Eight experimental channels each 487 meters in length composed of alternating pools and riffles (Fig. 1) are located on 34 acres of land leased from the Northern States Power company adjacent to the Monticello Nuclear Generating Plant. The average dimensions of a pool are 33 meters long by 4.0 meters wide by 0.6 meters deep; the riffles are approximately 33 meters long by 2.6 meters wide by .33 meters deep. Mississippi river water was pumped in at one end of each channel and returned to the river through a culvert at the lower end of the channel. Separate instrumentation systems monitored pH, temperature, dissolved oxygen, and light intensity at various locations along a selected channel.

Experiments planned at the Monticello Research Station involving manipulation of light intensity, pH, temperature, and dissolved O_2; necessitated a high degree of precision and reliability in monitoring fish movement. To achieve the design specifications and to allow easy adaptation to different experimental situations, a monitoring system controlled by a micro-processor was designed. Design and construction of electronic hardware was performed at the Cedar Creek Bioelectronics Laboratory and final field tests were conducted at the Monticello field station during May 1979.

Figure 1. Experimental Channel Schematic


EXPERIMENTAL CHANNEL SCHEMATIC
13
12
11
10
9
8
7
6
5
4
3
2
FLOW RATE = 270 gal / min
MAIN SIGNAL CABLE
2.6 M
0.33 M
RIFFLE CROSS SECTION
4.0 M
0.6 M
POOL CROSS SECTION
H2O
8.15°C
RECEIVER & MICROPROCESSOR

SECTION 2

CONCLUSIONS

The system designed and built under this contract determined the location of radio-tagged fish to the nearest pool or riffle area. A microprocessor was used to control all functions of the system, keeping track of time-of-day, printing location data, and determining signal quality. The system was low in cost, easy to install, and used readily available components. Sample rates and other parameters were easily changed via keyboard input. Using this system, researchers could collect behavioral data under semi-natural conditions without disturbing the fish. It was designed for unattended operation allowing continuous collection of data.

The results of the performance test conducted with this automatic radio tracking system indicated that fish could be located to the nearest pool or riffle area at the Monticello E.R.S. with an accuracy of 98.7%. Open channels were used to monitor background electronic interference and reference transmitters continously verified system reliability throughout the experiment.

Field tests indicated that the data produced by the tracking system was sufficiently comprehensive to determine changes in walleye behavior with respect to external influences. The system provided enough data on individual fish to detect changes in movement and resting patterns in addition to observing overall location preferences (Zinnel 1980).

Transmitter effects studies indicated that radio-tagged adult white sucker mortality was high enough to preclude gathering meaningful data on this species. We believe that transport, tagging and release into a

relatively restricted, shallow and highly productive environment all contribute in a cumulative manner to white sucker mortality. Limited work with other species suggested that northern pike and walleye may be preferable test species for use with radio telemetry studies at the Monticello E.R.S.

SECTION 3

RECOMMENDATIONS

Fish behavior relative to environmental alterations can be studied with the automatic radio tracking system developed for this contract. Experimental stream channels at the Monticello E.R.S. approximate a running water environment; thus data obtained should be more appropriate to questions concerning stream or river ecology and more definative than laboratory data. The radio tracking system developed and tested under this contract will permit researchers to observe mortality, avoidance behavior and changes in activity patterns resulting from various toxicant discharge schemes utilizing sublethal concentrations. Since fish behavior can be a sensitive indicator of environmental disturbance (Warner et al. 1966), experimentation conducted at the Monticello E.R.S. utilizing this system can provide quantitative data for evaluation of water quality criteria.

Bioeffects observations indicate that of the species tested, walleye and northern pike have the fewest post tagging survival problems. Moreover results indicate that white suckers should be avoided for future radio telemetry work at the Monticello Ecological Research Station.

SECTION 4

ENGINEERING DESIGN

MATERIALS

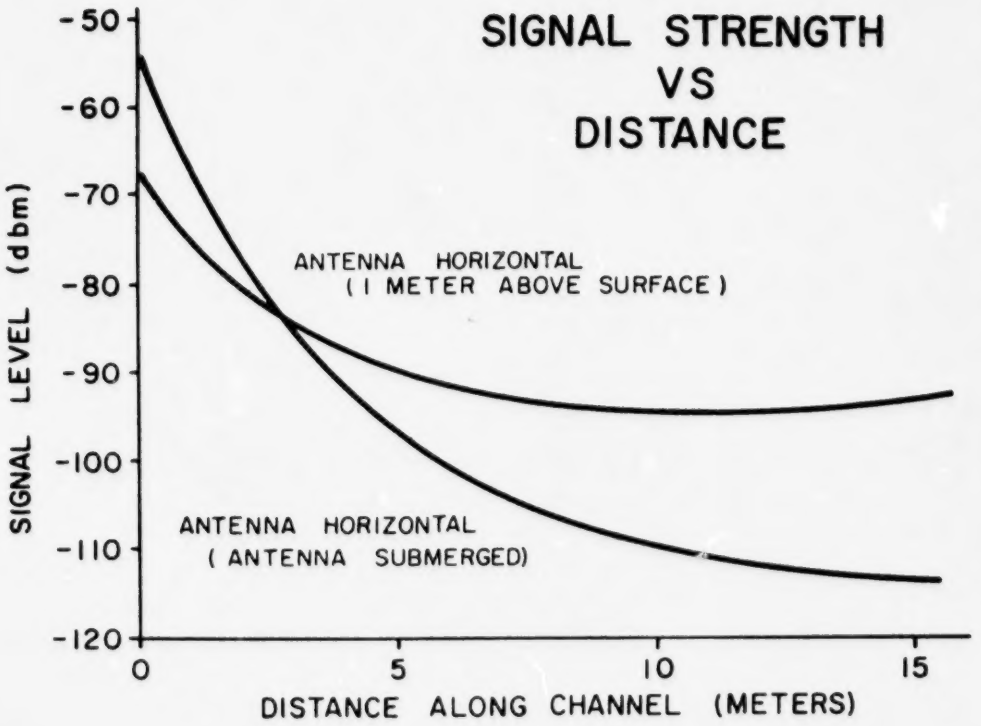
Of the several different techniques that could be used to meet the requirements of locating 30 fish to the nearest pool or riffle at 15 min intervals, the technique chosen measured radio frequency (rf) signal intensity for each fish at the various pool and riffle areas. A primary reason for deciding to use this type of system was because rf technology could be readily implemented at a reasonable cost. Prior experience with systems of this type (Ross and Siniff 1980) reduced the amount of time needed to complete the development. RF tags were chosen because the channels at Monticello often have dense stocks of vegetation which would impede the transmission of sonic signals (Stasko and Pincock 1977) and because fresh water facilitates transmission of an rf signal. Additionally, sonic transmitters have normally used hydrophones (Kuechle 1982), a very high impedance device, to detect the energy. The high impedance, unbalanced nature of these devices has made shielding to avoid pickup interference a difficult task. The low impedance RF antennas selected were balanced to fit the needs of the experimental situation.

The antenna pickup field for this situation could be termed "quasi-near field"; i.e. strength was expected to fall off as a function of $1/r^2$ near the antenna and $1/r$ toward the end of each pool or riffle area (r was the distance from transmitter to antenna). The goal was to have the signal fall off rapidly to achieve a maximum signal difference between the different antennas.

Several different antenna types were tested including vertical dipoles, loop antennas, and horizontal dipoles. Antennas were tested both in and out of the water. The antenna chosen was a horizontal dipole with the axis of the antenna parallel to the channel. The antennas were centered on the pool and riffle areas and mounted approximately one meter above the surface. The dipole configuration was chosen because of its optimum signal strength versus distance characteristic (Fig. 2), ease of implementation, freedom from adjustment, and stability over time. Although the submerged antenna was found to have a better field strength versus distance characteristic (Fig. 2), the above surface version was chosen to avoid potential damage problems from in-channel operations (vegetation removal, etc.).

The antennas were sampled via a coaxial cable connected to a control box to allow switching to the appropriate antenna when requested by the microprocessor. The main signal feed cable (Fig. 1) was a low-loss coaxial type used for direct burial in closed circuit television systems. Signal loss rate was low, 1.7 db per 100 meters, which minimized the difference in signal levels from the far ends of the cables compared to those near in the main line junction. In addition, the signal was taken off the center of the system rather than the near end to help equalize losses. A signal amplifier was placed at the main cable junction to prevent signal to noise deterioration in the main cable. Maximum difference in signal that could occur due to cable transmission was 3 db. Although this was higher than desired, we did not believe it was significant when compared to other variables affecting signal

Figure 2. Signal Strength vs Antenna Design


SIGNAL STRENGTH
VS
DISTANCE
-50
-60
-70
-80
-90
-100
-110
-120
SIGNAL LEVEL (dbm)
ANTENNA HORIZONTAL
(1 METER ABOVE SURFACE)
ANTENNA HORIZONTAL
(ANTENNA SUBMERGED)
0
5
10
15
DISTANCE ALONG CHANNEL (METERS)

levels. Performance tests later confirmed that cable losses were not a significant factor.

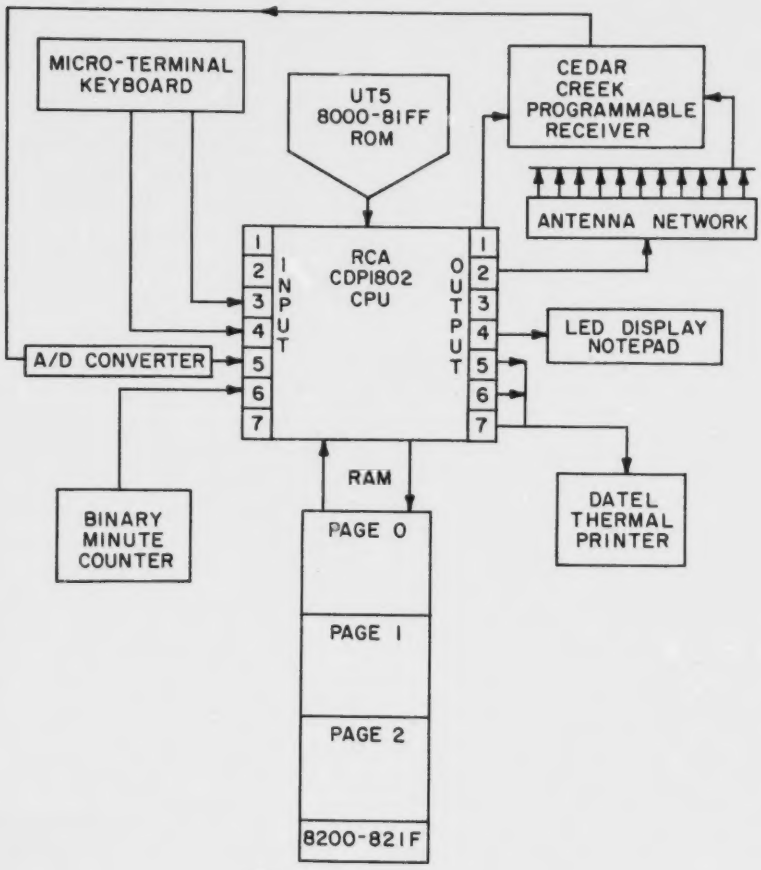
Antenna switching was controlled by a 4-bit binary select code issued by the microprocessor (Fig. 3). Each relay box contained a 4 to 16 line decoder, relay driver, and a relay that connected the selected antenna. All boxes and cable connectors were weatherproofed.

The receiver used for this application was a standard programmable memory receiver designed by the Cedar Creek Bioelectronics Lab with 64 channels of digital memory which allowed preprogramming of transmitter frequencies (Appendix C). Pre-selected frequencies were recalled by the microprocessor selecting 1 of the 64 memory locations. The signal from the receiver was detected, fed through a low pass filter to an 8 bit analog to digital converter for measurement. Data were recorded on a Datel thermal printer, model number DPP-Q7. Copies of the circuit diagrams for the complete system have been furnished to the project officer.

In order to automatically track rf-tagged fish, the organization and operation of MRSS was designed using a RCA COSMAC microprocessor (CDP1802) central processor unit (CPU). The CDP1802 was selected because CMOS (complementary metal oxide semiconductor) technology components consume less power than those of TTL (transistor-transistor logic) design and have a higher noise immunity, thus allowing construction of hardware suitable for field situations. Most of the 91 available microprocessor instructions (including 14 input/output instructions) were one memory word (8 bits) in length, but some required 2 or 3 words per operand (Appendix A). all eight classes of CDP1802 instruction functions were

Figure 3. MRSS Hardware Configuration

MRSS HARDWARE CONFIGURATION



used by MRSS; memory reference, register operation, logic operations, arithmetic operations, branch, skip, CPU control, and I/O byte transfer.

MRSS instructions resided in two types of memory; read only (ROM) and read/write (RAM). Alterable memory locations were organized according to a "page" system. The Monticello Remote Sensing System had three 256_{10} byte RAM components referred to as Page Zero (0000-00FF), Page One (0100-01FF), and Page Two (0200-02FF); and one 512 byte ROM at addresses 8000-81FF for the utility program that controlled the system micro-terminal. In addition, another 32-byte RAM was used for register storage by the utility ROM at memory addresses 8200-821F. Along with the six peripheral devices shown in Fig. 3, the microprocessor and the memory components comprised a simple computer system dedicated to radio tracking fish.

The University of Minnesota Cyber 74 time-sharing facility, under the NOS 1.2 operating system, was used to generate the hexadecimal machine language instructions for the micro-processor with the RCA support package, a cross-assembler and debugger written in FORTRAN. MRSS software was written in RCA COSMAC assembly language which allowed programs to be written and modified using mnemonic symbols rather than manipulating machine binary instruction codes. Moreover, the Cyber 74 time-sharing system provided facilities for archiving previous, current, and future versions of programs as well as simulated operation of the programs before field testing.

A portable data entry/readout device designed to operate with the CDP1802 central processor unit and utility program (UT5) was used to enter system commands (Fig. 3). This microterminal or "notepad" was a

low power, low cost, small-size alternative to the teletypewriter frequently used as an input device with small computer systems. It was particularly effective in a field situation where portability was a major objective.

The programmable scanning RF receiver was manufactured at Cedar Creek as described by Tester and Siniff (1976), Kuechle et al. (1971); and was used to detect radio transmitters functioning in the 53 MHz band. After a transmitter was attached to a fish, its frequency was entered into the memory of the receiver to he nearest kHz (Appendix D), which was thereafter associated with a particular selected code known as a "channel". MRSS allowed 32 channels to be scanned per cycle, but the potential system capability was 64 channels. Cedar Creek receivers are built to cover a 1 MHz frequency range, which discriminates 100 different frequencies at recommended spacings of 10 kHz intervals. An analog to digital (A/D) conversion of the signal intensity at the selected antenna was initiated by the micro-processor after allowing for "settling" time, and the resulting binary value was stored in an array for subsequent analysis.

To record time of day, a binary minute counter was tied to the 2 MHz clock on the CPU board. The microprocessor read the binary minute counter as a peripheral device to determine elapsed time (Fig. 3). Both time and location information were recorded by a Datel Thermal printer, model DPP-Q7. This six character per line, non-impact printer was TTL (Transistor Transistor Logic) rather than CMOS (Complementary Metal Oxide Conductor), but also had a low power consumption characteristic suitable for field installations.

Thus the primary hardware components of the fish tracking system designed for use at the Monticello E.P.A. Research Station were a micro-processor, a programmable scanning rf-receiver, an antenna network for sampling the signal strength of radio-transmitters attached to fish, and a printer to record location and time of day information. The data recorded by this system were continuous, instantaneous and without observer bias.

METHODS

MRSS Operator's Instructions Summary

It was assumed that the operator would become familiar with the operation of the system micro-terminal (notepad) as described in Appendix D. There were 3 functions for which the notepad was used by MRSS: (1) starting/stopping automatic tracking, (2) entering the day and the time, and (3) turning on/off frequency select codes for individual radio transmitters. All data values and memory addressed were displayed and entered in hexadecimal.

(1) Stopping automatic tracking was accomplished by depressing the "reset" (RST) key followed by "run utility" (RU) on the notepad. Because the time information was not updated when the system was not running, these parameters had to be entered when MRSS was started again.

(2) To enter day number, RST was pressed followed by RU, then the memory address field was set to 0064. Next the data entry mode (↔) was switched and the desired value entered for day number. Then (INC) was pressed to store the value in location 64.

(3) To enter hour (military time), RST was pressed followed by RU, then the memory address field was set to 0063. Next the data entry mode ( ) was switched and the desired value entered. Then INC was pressed to store the hour in location 63.

(4) To enter minute (00-3B), the procedure was repeated (3) using memory address 0062.

(5) Automatic tracking was started by pressing RST followed by "run program" (RP). The LED readouts disappeared and the system printed a blank line followed by the day and time at the beginning of the cycle.

MRSS had 32 frequency select codes (1F-00) defined in memory addresses 30 through 4F. Each frequency select code corresponded to a particular "channel" of the rf-receiver. Before tracking, frequencies had to be entered into the BCD memory of the receiver corresponding to the select codes used. The uppermost bit (7) was set (=1) if a frequency select code was not used for tracking (i.e. there was not a corresponding frequency for the receiver).

(6) RST was pressed followed by RU, then 0030 was entered in the memory address field. Next INC was pressed until the select code to be turned ON/OFF appeared in the data field. After switching to data entry mode (↔), a 9 was entered if the left character was a 1, or an 8 if the left character was a 0 followed by the right character, then INC was pressed to store the value back into the memory location. For example, to turn select code 17 off because only select codes 16-00 were needed, a 97 was

entered and then stored (INC) in memory address 0038. If an additional frequency was to be tracked, then memory address 0038, which would have originally appeared as 97, had to be changed to 17.

Detailed Software Design and Implementation

As described in the materials section, the microprocessor and peripheral devices comprised a simple flexible monitoring system. Use of a software program to control events meant adaptability to many different experimental situations without hardware redesign. Other advantages included accurate time-of-day information, speed of operation providing instantaneous observations, and ability to check quality of data.

MRSS had twelve distinct software modules, each performing a particular task, that together comprised the application program. This section discusses the function, timing and organization of each module; a complete listing can be found in Appendix B. In order of program origin, the modules were defined as: Bootstrap, Channel Ready List, Delay Loop, Binary to BCD Conversion, Initialization, Reset for Cycle, Print Cycle Headings, Pass Initialization, Channel Skip, Antenna Switching, Result Calculation, and Update System Clock. The program also contained areas of memory used as data storage buffers and were modified via installation parameters.

MRSS was initiated by pressing "Reset" and "Run Program" on the micro-terminal notepad. Effecting a "Master Clear", the program begun execution at location 0000 with scratch pad register zero as the program counter. The bootstrap segment of code set up scratch pad register 3 as the application P-counter and transfered control to the initialization

segment. Memory was organized so that the more mutable locations were in Page Zero, but the bulk of the code resided in Page One.

The Channel Ready List was an array of permissable frequency select codes. During field testing of MRSS, codes 0 to 31 were defined, having the same function as the memory channel selector switch on the front panel of a radio tracking receiver. The Cedar Creek programmable receiver used with MRSS had a BCD memory allowing frequency to be paired with channel select codes. After establishing the best frequency to be used for a particular radio transmitter, the three front panel frequency selector switches and the memory write selector were used to enter the frequency in kHz. The corresponding frequency select code was then turned on in the Channel Ready List via the notepad by changing bit 7 from one to zero. For example, to track a fish whose frequency was selected by channel 00 in the receiver, the contents of the list location (4F) must be changed from 80_{16} to 00_{16}. The current day, hour, and minute were entered in hexidecimal into locations 64_{16}, 63_{16} and 62_{16} respectively. MRSS updated these time parameters while running, but could be stopped and reset at any time by using the "Reset" and "Run Utility" keys of the notepad.

To control the timing of events such as issuing frequency select codes, switching antennas, initiating A/D conversions, and waiting for the printer, the micro-processor executed a "delay" function. The Delay Loop subroutine used 980 milli-seconds (msecs) to execute, primarily while waiting for the completion of an external event, such as printing a line. If a print command was issued less than 330 msecs after the previous print command, the data would be lost because the printer was

still "busy". There were only two scratch pad memory registers used by the delay subroutine, R(D) as the p-counter and R(2) as the delay counter.

A Binary to BCD Conversion subroutine was used to convert binary data values to their BCD equivalent as necessary for the recording of data by the thermal printer. Usage of four scratch pad memory registers was required for this purpose: the p-counter (R(7)), a pointer to the address of the data value to be converted (R(B)), another register pointing to where in memory to store the BCD result (R(C)), and also a register for intermediate arithmetic results (R(4)).

The Initialization module insured that a current clock reading was obtained from the binary minute counter each time the application program was started. Users were responsible for entering the correct time before starting, but the system updated these values at the end of each cycle by comparing previous and current readings of the binary minute counter.

The Reset for Cycle module was always executed at the begining of each cycle which occured only at fixed intervals specified by installation parameters. Because 4 readings per hour were required, each active frequency was sampled with all twelve antennas once every 15 minutes and the results printed. However, this installation parameter had a minimum limit of one cycle every 4 hours and a maximum of one cycle every 7 minutes for 32 channels or 15 minutes for 64 channels. Reinitialization of all operating registers occured at the beginning of each cycle of the main program.

A blank line to separate data recorded for each cycle, followed by the time, was printed at the beginning of each cycle. Because of the need to convert data to BCD and then wait for the printer to go "not busy", this segment used around 2500 msecs to execute. Scratch pad

register E was used as a pointer for the printer output buffer, plus the other registers required for passing parameters to the delay and conversion subroutines.

A pass consisted of a sequential scan of all 12 antennas on one particular frequency corresponding to a channel in the ready list. The antennas were sampled beginning with #13, which has located farthest away from the Lab (Fig. 1.) and ended the pass with the antenna located at the closest station, (#2). Before the pass was made, the frequency select code in the channel ready list was tested to determine if bit 7 was set; if not, the pass was initiated. If bit 7 of the select code was set, this indicated the frequency for this channel was not to be used this cycle, instead, the microprocessor proceeded to the next frequency select code in the channel ready list. The channel select code for a particular pass was output via I/O port #1, followed by a 1 second delay while the microprocessor waited for the receiver to lock on to the requested frequency. At the beginning of each pass, the memory storage location for the sum of the signal intensity readings (VSUM) was set to zero.

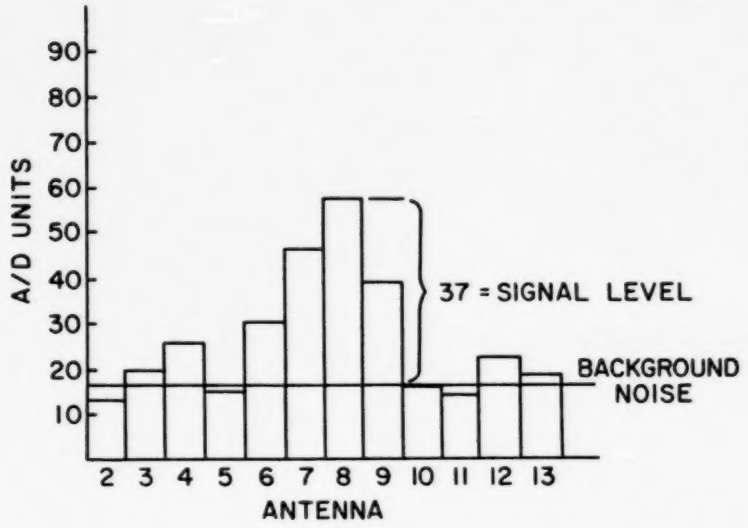
The antenna select codes were output to the network over I/O port #2; followed by a delay of 2 seconds before initiating the A/D conversion, thus allowing the signal to settle. After initiating a conversion, the CDP1802 waited until error flag #1 (EF1) went zero before reading the A/D result for that antenna latched into I/O port #5. Each unit resulting from an A/D conversion represented 20 millivolts of signal intensity. The reading obtained for each antenna was compared against the current maximum value for the pass in progress and, if the value just read exceeded the current maximum, scratch pad register B was set to the memory address where the just read signal intensity value was stored.

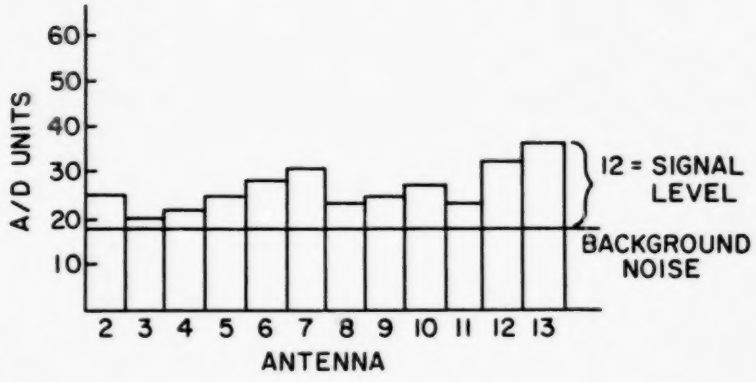
Each A/D value was divided by sixteen and added to the current pass total in memory location VSUM. If the address pointer in scratch pad register A was not equal to the end of the antenna select code array, the program branched back to select the next antenna in the list.

When the end of the list was reached, the pass was complete. Then the number of the antenna with the maximum A/D reading was computed by a logical 'and' of a four bit mask with the memory address of the maximum A/D reading. This antenna ordinal was then converted to BCD and stored in the printer output buffer as characters 3 and 4. This number, which corresponded to a physical pool or riffle, was the location of the transmitter. The quantity contained in VSUM was a measure of the level of background noise occuring during the just completed pass. As shown by Fig. 4a, a distinct signal had a pronounced center of mass around the antenna with the strongest signal, while an open channel with only noise appeared as in Fig. 4b. Since, an average of the 12 A/D values obtained from a normal transmitter gave an unreasonably high estimate of the background noise because each neighboring antenna also registered some signal (Fig. 4a); the sum of the 12 A/D values was divided by 16 instead of 12.

This background noise level estimate (VSUM/16) was then subtracted from the maximum A/D reading obtained from the antenna corresponding to the location of the transmitter to calculate the "level of signal distinctness". The larger this value, the more distinct the signal was at the antenna number reported as the transmitter location. The formula used for calculating level of signal distinctness when recording locations resulted in an index used to determine the quality of the

Figure 4. Raw Data Characteristics


90
80
70
60
50
40
30
20
10
A/D UNITS
37 = SIGNAL LEVEL
BACKGROUND NOISE
2 3 4 5 6 7 8 9 10 11 12 13
ANTENNA

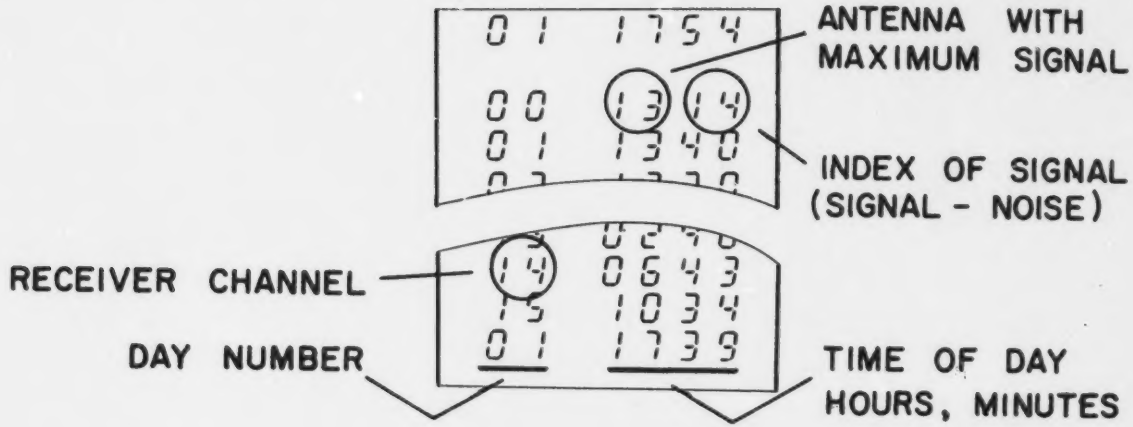

60
50
40
30
20
10
A/D UNITS
12 = SIGNAL LEVEL
BACKGROUND NOISE
2 3 4 5 6 7 8 9 10 11 12 13
ANTENNA

data. The level of signal distinctness was then converted to BCD and stored in the printer output buffer as characters 5 and 6. Finally the channel number that corresponded to the frequency used for the pass was converted to BCD and stored in the printer output buffer as characters 1 and 2. Subsequently, the line was output to the printer using I/O ports 5, 6, and 7; with the six characters being latched into a holding buffer until the activity on port 7 initiated printing.

After the results of the pass were printed (Fig. 5), the address in scratch pad register 8 was compared to the last address of the Channel Ready List. If not equal, the program began a new pass with the next frequency select code. If the last frequency select code was reached the cycle was complete. The clock value for the start of the last cycle was stored into the previous clock memory location and a new value for the next cycle was obtained by reading a value from the binary minute counter on I/O port #6. The number of minutes elapsed since the beginning of the last cycle was calculated and used to update the memory locations reserved for the day, hour and minute information. If the maximum value for day (99) was reached, it was reset to zero. The values for hour and minute were kept in standard military time. A one second delay for the completion of printing was executed before branching back to the beginning of the main program to begin a new cycle.

Thus, the major advantage of developing an automatic radio-tracking system controlled by a micro-processor was in the reduction of raw data to an easily understood summary form. Also of importance was the resulting high degree of accuracy and reliability in monitoring the location of rf-tagged fish together with uniformity of observation over a long period of time.

Figure 5. Data Printout


01 1754
00 13 14
01 1340
14 0643
15 1034
01 1739
ANTENNA WITH MAXIMUM SIGNAL
INDEX OF SIGNAL (SIGNAL - NOISE)
RECEIVER CHANNEL
DAY NUMBER
TIME OF DAY HOURS, MINUTES

SECTION 5

RESULTS

Data recorded by MRSS for each transmitter consisted of a frequency number, the antenna designation for the pool/riffle determined to be the location of the transmitter, and the level of signal distinctness, a signal to noise ratio analog for each location determination (Fig. 5). When the data tapes were transcribed, each line of location data became a computer card (case) containing the following information: date and time at the beginning of the cycle, a unique designation assigned to each frequency sampled, channel code used by MRSS, antenna ordinal of the transmitter location, level of signal distinctness, transmitter type and transmitter frequency. Following the encoding process, the raw data cards were read into a 'permanent file' on the Cyber 74 and prepared for analysis.

To prepare the raw data for input to the SPSS statistical package, a computer program was used to calculate movement information. First the raw data were sorted into ascending sequential order according to the following hierarchy: identification number, date, time and receiver frequency select code. To insure that movement parameters were generated only for location determinations with the required temporal spacing, a julian date was calculated using JDATE = (DAY*24*60)+(HOUR*60)+MINUTE. Movement was defined as a change in position as denoted by the absolute difference (moves) in station number between two successive location determinations no more than 15 minutes apart for the same identification number unique to each transmitter or open channel frequency. Another parameter (DIRECTION) was set to 0 if no movement was indicated, to 1 if

the change of position indicated movement up the channel towards station #2, or to 2 if the movement was down the channel toward station #13.

The third parameter (CHANGE) denoted change of direction of movement and was only calculated for 3 successive location determinations in a 30 minute period. The change parameter was blank if there was no movement, 0 if there was only one isolated movement, 1 if the three location determinations indicated two sequential movements in the same direction, or 2 if the two sequential movements were in opposite directions.

Finally, the composite data were processed into an SPSS system file for subsequent analysis. At this time, if any variables were found to have invalid parameters (possibly garbled in the transcription process) the entire case was deleted. The 36,290 cases used for analysis fell into 3 categories as summarized in Table 1: (1) reference transmitters (identification number calculated as 4000 plus the number of the pool where they were stationed), (2) walleyes (identification numbers corresponded to actual Atkin's tag attached to dorsal fin, 4038-4047), and (3) open channels (identification number calculated as 4100 plus channel number (0-3) used to record on printout).

System Verification

The performance characteristics of transmitters, were measured using the standard deviation of the signal level for reference transmitters from Table 1 as an indication of variability in the signal level for the different transmitter types. Continuous transmitters were the least variable, fast pulsing were slightly less variable than the medium

Table 1. Summary of the information produced by MRSS during field testing.

53 MHZ Frequency	Atkin's Tag Designation	Number of Locations Determinations	Average Signal Level in A/D Units	S.D. of Signal Level	Transmitter Type
.030	4002	79	43.5	8.4	SP
.020	4004	79	43.3	3.6	FP
.040	4006	79	38.9	4.7	MP
.450	4008	2490	15.0	2.2	CN
.100	4010	79	36.8	4.6	MP
.200	4012	2491	53.1	8.4	SP
.210	4038	2123	44.6	19.2	CN
.180	4039	1877	35.5	7.2	FP
.230	4040	2489	24.2	4.8	MP
.220	4041	2492	25.6	8.6	FP
.240	4042	2492	42.3	10.3	SP
.060	4043	2492	26.9	4.9	MP
.100	4044	1135	30.4	7.0	MP
.020	4045	2402	31.1	7.7	FP
.030	4046	2401	28.8	7.3	SP
.040	4047	1136	25.8	7.1	MP
.010	4100	2489	9.3	1.8	OC
.120	4101	2487	18.0	5.7	OC
.260	4102	2488	12.4	3.9	OC
.380	4103	2490	10.7	3.2	OC

'CN' = Continuous
'OC' = Open channel
'SP' = Slow pulsing
'MP' = Medium pulsing
'FP' = Fast pulsing

pulsing, and the slow pulsing transmitters were four times more variable than the continuous types. Calculation of the coefficient of variation for the signal levels of each transmitter indicated that variability for transmitters in fish, or for open channels, was twice that of transmitters used as references. However, when the coefficients of variation were compared for the references versus fish and for the reference versus open channels using the t-statistic, there were no significant differences.

As the field testing progressed, there appeared to be a slight tendency for signal levels to gradually become lower, presumably a function of water temperature, water conductivity changes, or the battery being drained of power. This was confirmed by analysis of covariance on the data for signal level for six walleyes that survived the entire period. The most significant factor was the inherent signal level of each transmitter, with the date (i.e. length of time in operation) half as important. The lowest levels of signal distinctness occurred during the 1200-1559 time period and the highest during 2000-2359. Effect for time-of-day was not significant, only varing by 2.25 units. Average levels of signal distinctness for individual walleyes could vary by 20 units of signal intensity, depending upon where the fish were positioned in a pool. Comparing average levels of signal distinctness for each transmitter in each pool/riffle suggested that riffles generally had lower signal levels than pools, but analysis of covariance did not detect a significant effect.

Location determinations could be further classified according to the level of signal distinctness recorded when the location of the

transmitter was assigned to a particular pool/riffle. The frequencies with which signal levels were found to occur during field testing suggested a trimodal distribution such that a 'poor' quality location determination was defined as having a level of signal distinctness less than 20 A/D conversion units. 'Good' quality fixes fell in the range of greater than 20 but less than 50 A/D units, while signal levels greater than 50 were 'excellent' quality fixes; and, as discovered by manual accuracy testing, these only occur when a strong transmitter was directly in front of an antenna installation.

Table 2 summarizes the data on signal quality including the percent of location determinations in each usage category that achieved a particular level of signal distinctness, and also the percent of each quality category attributed to usage. These data indicated signal levels for walleye transmitters were much more distinct than the open channels, i.e. high enough to have overrode interference. There were good and excellent quality signal levels for the open channels which probably resulted from a vehicle with an unshielded ignition system being too close to the instrumented channel or from lightening discharges.

Since two factors, signal level and variability, could have affected the accuracy of MRSS, a weak but continuous type transmitter (4008=53.450 MHz) was used for the reference at station # 8, and a strong but slow pulsing and, therefore, variable signal level type (4012=53.200 MHz) was used for the reference at station #12. Almost all the fixes for reference 4008 were "poor" while the fixes for variable reference 4012 were either "good" or "excellent" (Table 3). In order to answer the question "Does a low level of signal distinctness affect accuracy?",

Table 2. Comparison of the three categories of location determinations (fixes) as a function of quality as determined by level of signal distinctness expressed in analog to digital conversion units.

Statistic	Reference	Walleye	Open Channel
Average Signal:	34.45	31.47	12.69
S.D. for Signal:	19.51	11.69	5.20
N of fixes:	5297	21,039	9,954

Percent of total location determinations.

Signal Quality	Reference	Walleye	Open Channel
Poor	6.76	6.90	25.05
Good	3.74	47.04	2.46
Excellent	3.96	4.04	0.03

Percent of each usage category

Quality	Reference	Walleye	Open Channel
Poor	46.7	11.9	91.2
Good	25.9	81.1	8.7
Excellent	27.4	7.0	0.1

Percent of each quality category

Usage	Poor	Good	Excellent
Reference	17.5	7.0	49.3
Walleyes	17.8	88.3	50.3
Open Channels	64.7	4.7	0.4

it was necessary to consider the signal levels of the 68 errors that occurred during the 28 day test period. Errors were defined as a location determination recorded for a reference transmitter at some pool or riffle other than the true location.

Including all the reference transmitters from Table 1, there were 5297 location determinations on reference transmitters with 68 errors occurring, i.e. 98.72% accuracy. Moreover, 46.7% of all location determinations on reference transmitters were of "poor" quality and 61.8% of the errors occurred at these low levels of signal distinctness (Table 3). Correspondingly, 25.9% of the fixes were of "good" quality and accounted for 27.9% of the errors, while 27.4% of the reference location determinations were of "excellent" quality but included only 10.3% of the errors. To test whether transmitters with signal levels greater than 20 units are more accurate, a X^2 test with 1 df was made using the observed accuracy results for the reference transmitters. Expected values were calculated under the hypothesis of independence given the accuracy rate of 98.72%. From the results shown by Table 4, Ho can be rejected, concluding that there is a slightly higher error rate for "poor" signal level determinations ($>$ 20 units of signal intensity).

Assuming that the same proportion of errors would have occurred with low signal levels for rf-tagged fish, accurate data would have been assured by selecting for implantation only those transmitters with levels of signal distinctness greater than 20 units. Fortunately, Table 2 indicated that data recorded for walleyes during field testing of MRSS were primarily of good or excellent signal level quality. Moreover, a weak transmitter used as a reference (4008) contributed 61.8% of all

Table 3. Summary of location determinations on primary reference transmitters.

Quality	4008 (%)	4012 (%)
Poor	2472 (49.63)	1 (0.02)
Good	17 (0.34)	1065 (21.38)
Excellent	1 (0.02)	1425 (28.61)
Total Fixes	2490	2491

All errors occurring for reference transmitters.

Signal Quality	4008(%)	4010(%)	4012(%)	TOTALS(%)
Poor	42 (61.8)	0 (0.0)	0 (0.0)	42 (61.8)
Good	12 (17.6)	2 (2.9)	5 (7.4)	19 (27.9)
Excellent	1 (1.5)	0 (0.0)	6 (8.8)	7 (10.3)
Total Errors	55 (80.9)	2 (2.9)	11 (16.2)	68

Table 4. Chi-square test of accuracy for low signal level of distinctness.

Treatments	Accurate		Erroneous		Totals
Signal levels	Obs.	Exp.	Obs.	Exp.	
.LT. 20 A/D units	2432	2442	42	32	2474
.GE. 20 A/D units	2797	2787	26	36	2823
Totals	5223		68		5297

Ho: Occurence of errors is the same in the two different signal level groups: i.e. $P_1 = P_2$.

$$5.98 = ((\text{obs.} - \text{exp})^2/\text{exp}); \; X^2_{1(} = .025) = 5.02$$

reference errors from the half of those location determinations which were of poor quality. Since only 12% of the walleye data were of "poor" quality, it is probable that accuracy was closer to 99% for walleye location determinations.

Reliability of position information was also a function of each antenna in the network. Differences in sensitivity to radio signals or susceptibility to interference could have caused erroneous results. If this were the case during field testing, a characteristic pattern of location determinations for the open channels would have resulted from inequality of antenna function. As can be seen in Table 5, the percentages of the 3 quality levels of fixes which occured randomly at each antenna were quite different for the open channels versus walleye location determinations.

If the location determinations made by MRSS for the walleyes were random noise like the open channels, then they should have the same pattern of distribution. Using the actual number of locations that occurred at each antenna, from Table 5, where both fish data and open channel data were for the whole test period; a G^2 goodness-of-fit test (Fienberg 1977) was calculated as $G^2 = 2 \Sigma \text{Obs} \times (\log_{e(\text{Obs/Exp})})$. The resulting value for G^2 is 9226.5 with 11 d.f., and was tested by the values of the X^2 distribution. The value for X^2_{20} ($\alpha = .005$) = 40., signified that the pattern of distribution of fixes for the open channels and the walleyes were definitely not equivalent. Since the probability of the null hypothesis being correct was much less than .001, the individual antennas in the network were reliable and accurate to the nearest pool or riffle even though they were not equally distant from the receiver and conversion devices.

Table 5. Percent of location determinations of each signal level category occurring at each antenna in the network for walleyes and open channels.

	% Poor		% Good		% Excellent		N of Locations	
Antenna	Open	Fish	Open	Fish	Open	Fish	Open	Fish*
2	60.24	2.53	2.94	1.15	0.01	0.02	6341	597
3	5.79	0.26	2.14	0.55	0.01	0.01	766	128
4	7.33	0.84	0.55	7.68	--	1.57	766	1435
5	0.45	0.44	0.03	1.16	--	0.03	50	242
6	0.79	1.39	0.04	14.83	0.01	0.52	80	1279
7	9.51	1.34	0.56	3.93	0.01	0.12	1005	824
8	0.52	1.40	0.05	21.18	0.01	3.51	60	4858
9	0.71	0.81	0.06	3.95	--	0.16	79	838
10	0.38	1.40	0.01	15.22	--	0.25	40	2898
11	0.61	0.80	0.42	2.31	--	0.06	100	327
12	0.18	3.34	0.05	3.62	--	0.50	20	554
13	4.76	3.63	1.74	5.54	0.05	0.20	647	227
Total	91.23	11.91	8.67	81.12	0.10	6.97	9954	14207

* locations used only for surviving fish

SECTION 6

DISCUSSION

The Monticello remote sensing system has been shown to report accurate position information by time of day for individual radio transmitters. Location determinations on reference transmitters were 98.72% accurate and the level of signal distinctness was a reliable indicator of the quality of any location determination. Therefore, we concluded that MRSS provided reliable information on the location of free-ranging walleyes with implanted radio transmitters. The data were comprehensive enough to discern movement patterns in response to daily, or even hourly, fluctuations of light intensity or other external factors (Zinnel 1980).

Analysis of aquatic vertebrate behavior is a potentially useful technique for describing the effects of pollutant stress, a primary ecological concern of today. Because mortality is easy to detect and to correlate with significant changes in environmental conditions, the ways in which toxicants disrupt the biochemistry of an organism are easy to establish. Evaluating the effects of sublethal changes is harder but more valuable in the long run because the questions considered are relevant to the function and organization of individuals and groups of organisms. Whether a toxicant disrupts behavior in an individual, and whether this affects survival of groups in an ecosystem, are essential criteria for independent assessment of pollutant effects.

Small physiological changes in an organism are not necessarily deleterious and could well be within the normal range of adaptation for

the species. However, a lack of organization in movement or feeding behavior or inhibition of courtship behavior definitely compromise survival probabilities in aquatic vertebrates. A reduced scope of activity, a change in feeding, and avoidance reactions to introduced toxicants have been demonstrated in the laboratory (Chavin 1973). Changes in social interactions of fish when exposed to pollutants may provide the most sensitive and precise indicator of toxicant stress yet developed (Warner et al. 1966).

Most of the problems of interpreting avoidance reactions in nature can be attributed to the lack of continuous quantitative field observations. Subjectiveness of observers must be overcome and observations for different animals must be concurrent. But along with increased sample size comes the problem of evaluating the total set of results. MRSS represents an application of micro-computer technology to the problem of biological data acquistion. A sampling technique utilizing radio-telemetry does not have observer biases and provides reliable comparative data for measuring behavior.

During field testing, walleyes selected certain preferred locations. From the data recorded by MRSS, overall usage of available habitat was summarized as the percent of time spent in each pool or riffle. Location data were recorded continuously (15 minute intervals) and instantaneously, negating the usual problems with behavioral sampling techniques. Intensity and periodicity of movement (changes in position) were summarized for individual walleyes and a crepuscular activity pattern was characteristic of healthy fish. From paired samples of data produced by MRSS, social interaction between pairs of walleyes was

investigated by summarizing the distance separating each pair for each hour of the day (Zinnel 1980). These results demonstrated association between group members and avoidance of non-group individuals. MRSS was also useful for evaluating tagging recovery times, feeding behavior and pre-mortality movements.

SECTION 7

REFERENCES

Chavin, Walter (ed.), 1973. Responses of Fish to Environmental Change. Thomas Books, Springfield, Illinois.

Fienberg, S.E. 1977. The analysis of cross-classified categorical data. The MIT Press; Cambridge, Massachusetts.

Kuechle, V.B. 1982. State of the art of biotelemetry in North America. Sym. Zool. Soc. London, No. 49, P. 1-18.

Ross, M.J. and D.B. Siniff. 1980. Spatial distribution and temperature selection of fish near the thermal outfall of a power plant during fall, winter and spring. U.S. EPA Ecol. Res. Ser. EPA 600/3-80-009. 117 p.

Stasco, A., and G. Pincock. 1977. Review of underwater biotelemetry with emphasis on ultrasonic technique. J. of Fish. Res. Bd. Canada Vol. 34(9):1261-1285.

Tester, J.R. and D.B. Siniff. 1976. Engineering design and development p. 6-36. Annual progress report for Vertebrate Behavior and Ecology.

Warner, R.E., K.K. Peterson and L. Borgman. 1966. Behavioral pathology in fish; a quantitative study of sublethal pesticide toxication. Journal of Applied Ecology, Vol. (3) suppl., pp. 223-247.

Winter, J.D., V.B. Kuechle, D.B. Siniff, and J.R. Tester. 1978. Radio tracking freshwater fish. Report #152, Agriculture Experimental Station, University of Minnesota.

Zinnel, K.C. 1980. Behavior of walleye pike (Stizostedion vitreum vitreum) in experimental channels as monitored by a micro-computer utilizing radio-telemetry. M.S. Thesis, University of Minnesota.

SECTION 8

APPENDICES

A) Glossary

B) MRSS Program

C) Opperational procedures for system hardware

D) Effects of radio transmitters on the white sucker

APPENDIX A

GLOSSARY

This appendix describes the CDP1802 CPU architecture, modes, and states necessary to the understanding of the microprocessor instruction set utilization.

ALU - The Arthmetic and Logic Unit. The ALU performs the arithmetic and logic operations.

CMOS - Complementary Metal Oxide Semi-conductor.

D - The Data register (8 bits). This register is the machine accumulator used in performing arithmetic and logic operations. Data passing between memory and the scratch-pad registers go through D.

DF - The Data Flag (1 bit). Used and set or reset by the add, subtract, and shift instructions. It is also tested by the branch instructions.

IE - The Interrupt Enable flip-flop (1 bit). When IE is set to 1, interrupts are enabled; when IE is 0, interrupts are disabled.

I,N - The Instruction code and N field (4 bits each). These combined registers hold the operation code byte of the fetched instruction; I holds the higher four bits and N the lower four bits. In many cases, I specifies an instruction and N designates a scratch-pad register; otherwise, I and N together specify an instruction.

INC/DEC - The Increment/Decrement logic unit. This unit is used to either increment or decrement a designated register.

M - Memory (256 eight-bit bytes each of RAM or ROM per page).

P - The P designator register (4 bits). Its contents specify which of the scratch-pad registers is the current Program Counter, R(P). The program counter (P-counter) holds the address of the next instruction to be executed.

Q - The Q flip-flop (1 bit). Its contents can be set or reset by instructions and are available externally. It can be tested by certain branch instructions and is used as a general purpose flag.

R - An array of 16 scratch-pad Registers (16 bits each). All references to memory are made with the registers in R used as pointers. These registers may also be used to hold data and loop counters. The entire array is often referred to as a scratch-pad memory (SPM).

T - The Temporary register (8 bits). T can receive the contents of X in its higher four bits and the contents of P in its lower four bits, X and P can take new values and those saved in T can take new values and those saved in T can eventually be restored.

TTL - Transistor-Transistor Logic.

X - The X designator register (4 bits). Its contents specify which of the scratch-pad registers is used to address data. Data addressed by R(X) is used by many instructions, especially the arithmetic and logic ones.

Tables I to VIII describe the instruction repertoire of the RCA COSMAC central processor unit (With permission from RCA Corporation).

Table I. Memory Reference Instructions

Op Code	Mnemonic	Instruction	Action
0N	LDN	Load by N	M(R(N)) = D; for N≠0
4N	LDA	Load Advance	M(R(N)) = D; R(N)+1 R(N)
F0	LDX	Load by X	M(R(X)) = D
72	LDXA	Load by X Advance	M(R(X)) = D; R(X)+1 = R(X)
F8	LDI	Load Immediate	M(R(P)) = D; R(P)+1 = R(P)
5N	STR	Store by N	D = M(R(N))
73	STXD	Store by X and Decrement	D = M(E(X));R(X)-1 = R(X)

Table II. Register Operations

Op Code	Mnemonic	Instruction	Action
1N	INC	Increment	R(N)+1 = R(N)
2N	DEC	Decrement	R(N)-1 = R(N)
60	IRX	Increment Reg. X	R(X)+1 = R(X)
8N	GLO	Get Low	R(N).0 = D
AN	PLO	Put Low	D = R(N).0
9N	GHI	Get High	R(N).1 = D
BN	PHI	Put High	D = R(N).1

Table III. Logic Operations

Op Code	Mnemonic	Instruction	Action
F1	OR	Or	M(R(X)) V D = D
F9	ORI	Or Immediate	M(R(P)) V D = D; R(P)+1 = R(P)
F3	XOR	Exclusive Or	M(R(X)) TV D = D
FB	XRI	Exclusive or Immediate	M(R(P)) TV D = D; R(P)+1 = R(P)
F2	AND	And	M(R(X)) U D = D
FA	ANI	And Immediate	M(R(P)) U D = D; R(P)+1 = R(P)
F6	SHR	Shift Right	Shift D right one bit, LSB(D) = DF,0 = MSB(D)
76	SHRC RSHR	Shift Right with Carry Ring Shift Right	Shift D right one bit, LSB(D) = DF, DF = MSB(D)
FE	SHL	Shift Left	Shift D left one bit, MSB(D) = DF, 0 = LSB(D)
7E	SHCL RSHL	Shift Left with Carry Ring Shift Left	Shift D left one bit, MSB(D) = DF, DF = LSB(D)

Table IV. Arithmetic Operations

Op Code	Mnemonic	Instruction	Action
F4	ADD	Add	M(R(X))+D = DF, D
FC	ADI	Add Immediate	M(R(P))+D = DF, D; R(P)+1 = R(P)
74	ADC	Add with Carry	M(R(X))+D+DF = DF, D
7C	ADCI	Add with Carry Immediate	M(R(P))+D+DF = DF, D; R(P)+1 = R(P)
F5	SD	Subtract D	M(R(X))-D = DF, D
FD	SDI	Subtract D Immediate	M(R(P))-D = DF, D; R(P)+1 = R(P)
75	SDB	Subtract D with Borrow	M(R(X))-D-DF = DF, D
7D	SDBI	Subtract D with Borrow Immediate	M(R(P))-D-DF = DF, D; R(P)+1 = R(P)
F7	SM	Subtract Memory	D-M(R(P)) = DF, D;
FF	SMI	Subtract Memory Immediate	D-M(R(P)) = DF, D; R(P)+1 = R(P)
77	SMB	Subtract Memory with Borrow	D-M(R(X))-DF = DF, D
7F	SMBI	Subtract Memory with Borrow Immediate	D-M(R(P))-DF = DF, D; R(P)+1 = R(P)

Table V(a). Short Branch Instructions

Op Code	Mnemonic	Instruction	Action
30	BR	Short Branch	M(R(P)) = R(P).0
38	NBR	No Short Branch	R(P)+1 = R(P)
32	BZ	Short Branch if D Zero	If D=0, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
3A	BNZ	Short Branch if D Non-zero	If D=0, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
33	BDF	Short Branch if DF	If DF=1, M(R(P) = R(P).0; Else, R(P)+1 = R(P)
3B	BNF	Short Branch if Not DF	If DF=0, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
31	BQ	Short Branch if Q	If Q=1, M(R(P)) = R(P)0; Else, R(P)+1 = R(P)
39	BNQ	Short Branch if Not Q	If Q=0, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
34	B1	Short Branch if EF1	If EF1=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
3C	BN1	Short Branch if Not EF1	If EF1=0, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
35	B2	Short Branch if EF2	If EF2=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
3D	BN2	Short Branch if Not EF2	If EF2=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
36	B3	Short Branch if EF3	If EF3=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
3E	BN3	Short Branch if Not EF3	If EF3=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
37	B4	Short Branch if EF4	If EF4=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)
3F	BN4	Short Branch if Not EF4	If EF4=1, M(R(P)) = R(P).0; Else, R(P)+1 = R(P)

Table V(b). Long Branch Instructions

Op Code	Mnemonic	Instruction	Action
C0	LBR	Long Branch	M(R(P)) = M(R(P)+1) = R(P)
C8	NLBR	No Long Branch	R(P)+2 = R(P)
C2	LBZ	Long Branch if D Zero	If D=0, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)
CA	LBNZ	Long Branch if D Non-Zero	If D≠0, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)
C3	LBDF	Long Branch if DF	If DF=1, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)
CB	LBNF	Long Branch if DF	If DF=0, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)
C1	LBQ	Long Branch if Q	If Q=1, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)
C9	LBNQ	Long Branch if Not Q	If Q=0, M(R(P)), M(R(P)+1) = R(P); Else R(P)+2 = R(P)

Table VI. Skip Instructions

Op Code	Mnemonic	Instruction	Action
38	SKP	Short Skip	R(P)+1 = R(P)
C8	LSKP	Long Skip	R(P)+2 = R(P)
CE	LSZ	Long Skip if D Zero	If D=0, R(P)+2 = R(P)
C6	LSNZ	Long Skip if D Nonzero	If D≠0, R(P)+2 = R(P)
CF	LSDF	Long Skip if DF = 1	If DF = 1, R(P) + 2 = R(P)
C7	LSNF	Long Skip if DF = 0	If DF=0, R(P)+2 = R(P)
CD	LSQ	Long Skip if Q	If Q=1, R(P)+2 = R(P)
C5	LSNQ	Long Skip if Not Q	If Q=0, R(P)+2 = R(P)
CC	LSIE	Long Skip if IE	If IE=1, R(P)+2 = R(P)

Table VII. Control Instructions

Op Code	Mnemonic	Instruction	Action
00	IDL	IDLE	Wait for DMA or INTERRUPT; M(R(0)) = BUS
DN	SEP	Set P	N = P
EN	SEX	Set X	N = X
C4	NOP	No Operation	
7B	SEQ	Set Q	1 = Q
7A	REQ	Reset Q	0 = Q
78	SAV	Save	T = M = (R(X))
79	MARK	Mark	(X,P) = T = M(R(2)); P = X; R(2)-1 = R(2)
70	RET	Return	M(R(X)) = (X,P); R(X)+1 = R(X); 1 = IE
71	DIS	Disable	M(R(X)) = (X,P); R(X)+1 = R(X); 0 = IE

Table VIII. Input/Ouput Byte Transfer Instructions

Op Code	Mnemonic	Instruction	Action
6N(1≤N≤7)	OUT	Output	M(R(X)) = BUS; R(X)+1 = R(X); N=N Lines
6N(9≤N≤F)	INP	Input	BUS M(R(X)) = D; N-8=N Lines

APPENDIX B
PROGRAM

This appendix provides the computer program which controls the Monticello Remote Sensing System (MRSS).

```
MEMORY  COSMAC          CARD      SOURCE LINE
ADDRESS  CODE            #
   0000                  1        ORG  *
   0000 F8F0             2 INIT:  LDI  A.1(BGIN) .. BOOTSTRAP
   0002 B3               3        PHI  R3
   0003 F850             4        LDI  A.0(BGIN)
   0005 A3               5        PLO  R3
   0006 D3               6        SEP  R3    ..R3. IS MAIN P-COUNTER
   0007 00               7        IDL        ..SHOULD NEVER GET HERE
   0008                  8..      CONSTANTS USED
   0008                  9 ZERO   =    00    ..CONSTANT ZERO
   0008                 10 ONE    =    01    ..CONSTANT ONE
   0008                 11 TWO    =    02
   0008                 12 FOUR   =    14
   0008                 13 FIFN   =    15
   0008                 14 TEND   =    10    ..TEN DECIMAL
   0008                 15 CTEN   =   #10    ..HEX(BCD) TEN
   0008                 16 SIXT   =    60    ..CONSTANT DECIMAL SIXTY
   0008                 17 XXIV   =    24    ..CONSTANT DECIMAL TWENTY-FOUR
   0008                 18 MSK4   =   #0F    ..FOUR BIT MASK
   0008                 19 C100   =   100    ..MAXIMUM DAY COUNTER
   0008                 20 NINT   =   #90    ..BCD NINETY
   0008                 21 FILL   =   #FF    ..BLANK FILL CHARACTER
   0008                 22 MAX    =   #FF    ..MAXIMUM 8 BIT VALUE
   0008                 23 ..
   0030                 24        ORG #30
   0030 1F1E1D1C        25 FQTB:  ,31,30,29,28,27,26,25,24
   0034 1B1A1918
   0038 17161514                  26,23,22,21,20,19,18,17
   003C 13121110
   003F 0F0E0D0C                  27,16,15,14,13,12,11,10,9
   0044 0B0A0908
   0047 07060504                  28,8,7,6,5,4,3,2,1,0
   004C 03020100
   0050 0F              29 ENDF:  ORG  *
   0050                 30 ANTB:  =   ENDF-13..TWELVE ANTENNAS TO SCAN
   0050                 31 ENDT:  ORG  *
   0050                 32 NVLD:               ..INVALID ANTENNA SELECT CODE
   0052                 33 ..
   0050                 34        ORG #50    ..RESERVE A/D STORAGE ARRAY
   0050                 35 ATOD:  ORG *      ..LWA+1 OF A TO D VALUES
   0050                 36 ..
   0060                 37        ORG #60
   0060 00              38 CCLK:  ,0  ..CURRENT CLOCK READING
   0061 00              39 PCLK:  ,0  ..PREVIOUS CLOCK READING
```

```
0062 00          40 MINS:   ,0  ..BINARY MINUTE COUNTER
0063 00          41 HOUR:   ,0  ..BINARY HOUR COUNTER
0064 00          42 DAYS:   ,0  ..BINARY DAY COUNTER
0065 000000      43 PRNT:   ,0,0,0     ..PRINTER BUFFER
0068 00          44 HOLD:   ,0  ..HOLDS VALUES FOR CBCD SUBROUTINE
0069 00          45 ASEL:   ,0          ..CODE TO INIATE A/D CONVER
006A 00          46 VSUM:   ,0  ..A/D SUM
006B             47 ..
0080             48         ORG  #80
0080 F8FF        49 WAIT:   LDI  MAX   ..WAIT KILLS TIME
0082 A2          50         PLO  R2
0083 FF01        51 LOPR:   SMI  ONE
0085 C4          52         NOP
0086 3A83        53         BNZ  LOPR
0088 22          54         DEC  R2
0089 82          55         GLO  R2
008A 3A83        56         BNZ  LOPR
008C D3          57         SEP  R3    ..RETURN TO MAIN PROGRAM
008D 00          58         IDL
008E             59..
008E F800        60 CBCD:   LDI ZERO   ..CONVERT BINARY TO BCD
0090 5C          61         STR RC
0091 0B          62         LDN RB     ..RB HAS ADDRESS OF VALUE TO
0092 A4          63         PLO R4     ..R4 IS SCRATCH REGISTER
0093 84          64 LPCV:   GLO R4     ..REMAINDER
0094 FF0A        65         SMI TEND   ..SUBTRACT OFF DECIMAL TEN
0096 3BA1        66         BM  RNEG   ..UNTIL RESULT NEGATIVE
0098 A4          67         PLO R4
0099 0C          68         LDN RC
009A FC10        69         ADI CTEN
009C 5C          70         STR RC
009D FF90        71         SMI NINT
009F 3B93        72         BNF LPCV
00A1 0C          73 RNEG:   LDN RC     ..QUIT IF RESULT NEGATIVE
00A2 A5          74         PLO R5
00A3 84          75 TRYM:   GLO R4     ..RESTORE REMAINDER
00A4 32AA        76         BZ  FINIS
00A6 15          77         INC R5
00A7 24          78         DEC R4
00A8 30A3        79         BR  TRYM
00AA 85          80 FINIS:  GLO R5
00AB 5C          81         STR RC
00AC D3          82         SEP R3     ..RETURN TO MAIN PROGRAM
00AD 00          83         IDL
00AE             84 ..
00F0             85         ORG #F0
00F0 F800        86 BGIN:   LDI A.1(CCLK)..INITIALISE CLOCK
00F2 BE          87         PHI RE
00F3 F860        88         LDI A.0(CCLK)
00F5 AE          89         PLO RE
00F6 EE          90         SEX RE
```

```
00F7 6E          91          INP 6
00F8 F800        92 MAIN:    LDI A.1(INIT)
00FA B2          93          PHI R2
00FB B4          94          PHI R4
00FC B5          95          PHI R5
00FC B6          96          PHI R6
00FC B7          97          PHI R7
00FC B8          98          PHI R8
0100 B9          99          PHI R9
0101 BA         100          PHI RA
0102 BB         101          PHI RB
0103 BC         102          PHI RC
0104 BD         103          PHI RD
0105 BE         104          PHI RE
0106 F800       105          LDI ZERO
0108 A2         106          PLO R2
0109 A4         107          PLO R4
010A A5         108          PLO R5
010B A6         109          PLO R6
010C F867       110          LDI A.0(PRNT+2)
010E AE         111          PLO RE      ..PRINT A BLANK LINE
010F EE         112          SEX RE      ..BEFORE TIME AT BEGINNING OF
0110 F8FF       113          LDI FILL    ..STORE BLANKS
0112 73         114          STXD        ..IN PRINT BUFFER
0113 73         115          STXD
0114 5E         116          STR RE
0115 65         117          OUT 5
0116 66         118          OUT 6
0117 67         119          OUT 7
0118 F880       120          LDI A.0(WAIT)..DELAY FOR PRINT
011A AD         121          PLO RD
011B DD         122          SEP RD
011C F865       123          LDI A.0(PRNT)
011E AC         124          PLO RC
011F AE         125          PLO RE
0120 F864       126          LDI A.0(DAYS)
0122 AB         127          PLO RB
0123 F88E       128          LDI A.0(CBCD)...CONVERT DAYS TO BCD
0125 A7         129          PLO R7
0126 D7         130          SEP R7
0127 2B         131          DEC RB
0128 1C         132          INC RC
0129 F88E       133          LDI A.0(CBCD)...CONVERT HOURS TO BCD
012B A7         134          PLO R7
012C D7         135          SEP R7
012D 2B         136          DEC RB
012E 1C         137          INC RC
012F F88E       138          LDI A.0(CBCD)...CONVERT MINUTES TO BCD
0131 A7         139          PLO R7
0132 D7         140          SEP R7
```

```
0133 EE          141          SEX RE          ..(RE)=PRINT FWA
0134 65          142          OUT 5           ..CHARS 1 and 2 PRINTED
0135 66          143          OUT 6           ..CHARS 3 AND 4 TO PRINTER
0136 67          144          OUT 7           ..CHARS 5 AND 6 OUT AND ALL P
0137 F880        145          LDI A.0(WAIT)..WAIT FOR I/O TO FINISH
0139 AD          146          PLO RD
013A DD          147          SEP RD
013B F830        148          LDI A.0(FQTB)
013D A8          149          PLO R8
013E F843        150 CYCL:    LDI A.0(ANTB)..START NEW PASS
0140 A9          151          PLO R9
0141 E9          152          SEX R9          ..MAKE SURE BIT 4 NOT SET
0142 62          153          OUT 2           ..WHEN FREQUENCY CHANGES
0143 F880        154          LDI A.0(WAIT)
0145 AD          155          PLO RD
0146 DD          156          SEP RD
0147 F86A        157          LDI A.0(VSUM)..CLEAR A/D SUM
0149 AE          158          PLO RE
014A F85D        159          LDI A.0(ATOD)..SET UP A TO D STORAGE
014C AA          160          PLO RA
014D AB          161          PLO RB          ..SET UP HOLDER FOR MAX A TO
014E F800        162          LDI ZERO        ..CLEAR REGS
0150 5E          163          STR RE          ..CLEAR VSUM
0151 5A          164          STR RE          ..CLEAR FIRST A/D
0152 5B          165          STR RB          ..CLEAR MAX A/D
0153             166..
0153 08          167          LDN R8          ..IF BIT 7 OF FREQUENCY SELEC
0154 7E          168          SHLC            ..DO NOT USE THIS FREQUENCY
0155 3B5A        169          BNF OKTU
0157 18          170          INC R8          ..SET TO NEXT FREQUENCY
0158 30C1        171          BR SKIP
015A E8          172 OKTU:    SEX R8
015B 61          173          OUT 1           ..OUTPUT FREQUENCY SELECT COD
015C F880        174          LDI A.0(WAIT)..FOR I/O TO COMPLETE
015E AD          175          PLO RD
015F DD          176          SEP RD
0160 F869        177 AGIN:    LDI A.0(ASEL)
0162 AC          178          PLO RC          ..SAVE CONVERSION INITIATION
0163 E9          179          SEX R9          ..SELECT ANTENNA TO READ
0164 09          180          LDN R9          ..(D) = ANTENNA
0165 F910        181          ORI CTEN        ..(D) = ANTENNA # PLUS HEX 10
0167 5C          182          STR RC          ..SAVE IN ASEL
0168 62          183          OUT 2           ..OUTPUT SELECT CODE TO NETWO
0169 F880        184          LDI A.0(WAIT)..A.0(WAIT) FOR I/O TO FIN
106B AD          185          PLO RD
016C DD          186          SEP RD          ..JUMP TO DELAY SUBROUTINE
016D F880        187          LDI A.0(WAIT)...WAIT FOR 2 SECS
```

```
016F AD          188          PLO RD
0170 DD          189          SEP RD
0171 EC          190          SEX RD          ..R(C) POINTS TO ASEL
0172 62          191          OUT 2           ..REQUEST A/D CONVERSION
0173 C4          192          NOP
0174 C4          193          NOP
0175 3C73        194          BN1 *-2         ..WAIT TILL EF1 GOES ZERO
0177 EA          195          SEX RA          ..READ A/D FOR ANTENNA SELECT
0178 6D          196          INP 5
0179 A1          197          PLO R1          ..SAVE A/D IN R1
017A EB          198          SEX RB          ..SEE IF NEW READING IS LARGE
017B F7          199          SM
017C 3B80        200          BNF LTEQ        ..BRANCH IF LESS THAN OR EQUA
017E 8A          201          GLO RA          ..SET NEW MAX A/D ADDRESS
017F AB          202          PLO RB
0180 2A          203 LTEQ:    DEC RA          ..DECREMENT A/D STORAGE ADDRE
0181 F86A        204          LDI A.0(VSUM) ..DIVIDE A/D BY 16
0183 AC          205          PLO RD
0184 EC          206          SEX RC
0185 81          207          GLO R1          ..RESTORE A/D VALUE
0186 F6          208          SHR
0187 F6          209          SHR
0188 F6          210          SHR
1089 F6          211          SHR
018A F4          212          ADD
018B 5C          213          STR RD          ..STORE SUM BACK
018c 89          214          GLO R9
018D FF50        215          SMI A.0(ENDT) ..HAVE ALL ANTENNAS BEEN R
018F 3B60        216          BNF AGIN        ..IS PASS DONE?
0191 0B          217          LDN RB          ..YES, GET MAX A/D
0192 F7          218          SM              ..RX POINTS TO VSUM
0193 A1          219          PLO R1          ..SAVE DIFFERENCE
0194 3399        220          BDF NOTN        ..DF IS SET IF NO BORROW
0196 F800        221          LDI ZERO
0198 A1          222          PLO R1
0199 F866        223 NOTN:    LDI A.0(PRNT+1) ..GET SET TO PRINT RESULT
019B AC          224          PLO RC
019C 8B          225          GLO RB          ..COMPUTER ANTENNA DEFINITION
019D FA0F        226          ANI MSK4        ..LOWER 4 BITS OF ANTENNA ADD
019F A2          227          OKI R2
01A0 F868        228          LDI A.0(HOLD)
01A2 AB          229          PLO RB
01A3 82          230          GLO R2
01A4 5B          231          STR RB
01A5 F88E        232          LDI A.0(CBCD)
01A7 A7          233          PLO R7          ..CONVERT ANT # TO BCD
01A8 D7          234          SEP R7          ..FOR OUTPUT AS CHARS 3&4
01A9 1C          235          INC RC
```

```
01AA 81       236        GLO R1          ..PRINT DIFF
01AB 58       237        STR R8          ..STORE IN HOLD
01AC F88E     238        LDI A.0(CBCD) ..CONVERT DIF = MAX - BIAS
01AE A7       239        PLO R7
01AF D7       240        SEP R7
01B0 F865     241        LDI A.0)PRNT) ..NOW CHANNEL NMBR
01B2 AC       242        PLO RC
01B3 88       243        GLO R8
01B4 AB       244        PLO R8
01B5 2B       245        DEC R8
01B6 F88E     246        LDI A.0(CBCD) ..CONVERT FREQUENCY #
01B8 A7       247        PLO R7          ..OUTPUT AS CHARS 1&2
01B9 D7       248        DEP R7
01BA 65       249        OUT 5
01BB 66       250        OUT 6
01BC 67       251        OUT 7
01BD F880     252        LDI A.0(WAIT) ..DELAY FOR PRINTER
01BF AD       253        PLO RD
01C0 DD       254        SEP RD
01C1 88       255 SKIP:  GLO R8          ..SEE IF CYCLE DONE
01C2 FF50     256        SMI A.0(ENDF)
01C4 3B3E     257        BNF CYCL
01C6 E9       258        SEX R9          ..CLEAR A/D CONVERT
01C7 62       259        OUT 2           ..INVALID ANTENNA CODE
01C8 F800     260        LDI ZERO        ..CLEAR COUNTERS
01CA A4       261        PLO R4
01CB A5       262        PLO R5
01CC A6       263        PLO R6
01CD EE       264        SEX RE
01CE F860     265        LDI A.0(CCLK)
01D9 AE       266        PLO RE
01D1 72       267        LDXA            ..MAKE CURRENT CLOK PREVIOUS
01D2 73       268        STXD            ..STORE VIA X AND DECREMENT
01D3 6E       269 MN15:  INP 6           ..READ CURRENT CLOCK
01D4 1E       270        INC RE          ..R(X) = ADDRESS OF VALUE STO
01D5 F7       271        SM              ..SUBTRACT PCLK FROM A.0(CCLK
01D6 A1       272        PLO R1          ..SAVE MINS ELAPSED
01D7 FF0F     273        SMI FIFN        ..WAIT FOR 15 MINS
01D9 33E2     274        BDF NBRW        ..DF = 1 IF NO BORROW
01DB 2E       275        DEC RE          ..POINT TO CCLK
01DC F880     276        LDI A.0(WAIT) ..DONT HIT BMC TOO FAST
01DE AD       277        PLO RD
01DF DD       278        SEP RD
01E0 30D3     279        BR MN15         ..READ CLOCK AGAIN
01E2 1E       280 NBRW:  INC RE          ..NOW ADD MINS ELAPSED
01E3 81       281        GLO R1
01E4 F4       282        ADD             ..TO SYSTEM MINUTE COUNTER
01E5 A4       283        PLO R4
```

```
01E6 FF3C      284          SMI SIXT     ..SUBTRACT SIXTY MINUTES
01E8 3BEC      285          BNF CHUR     ..UNTIL LESS THAN A.0(HOUR)
01EA A4        286          PLO R4       ..SAVE REMAINDER
01EB 15        287          INC R5       ..INCREMENT HOUR COUNTER
01EC 84        288 CHUR:    GLO R4       ..GET REMAINDER
01ED 5E        289          STR RE       ..UPDATE MINUTE COUNTER
01EE 1E        290          INC RE       ..POINT TO HOURS
01EF 85        291          GLO R5       ..GET VALUE TO ADD TO HOURS
01F9 F4        292          ADD          ..UPDATE HOUR COUNTER
01F1 A5        293          PLO R5
01F2 FF18      294          SMI XXIV     ..SUBTRACT 24
01F4 3BF8      295          BNF CDAY     ..BRANCH IF LESS THAN DAY
01F6 A5        296          PLO R5       ..SAVE REMAINDER
01F7 16        297          INC R6       ..BUMP DAY SCRATCH
01F8 85        298 CDAY:    GLO R5       ..GET HOURS REMAINING
01F9 5E        299          STR RE       ..UPDATE SYSTEM HOUR COUNTER
01FA 1E        300          INC RE       ..NOW LOOK AT DAY COUNTER
01FB 86        301          GLO R6       ..ADD NEW A.P(DAYS)
01FC F4        302          ADD          ..RESULT IN D-REG
01FD A6        303          PLO R6       ..SAVE IN R6
01FE FF64      304          SMI C100     ..MAX DAY IS 99
0200 3B05      305          BNF DONE     ..IF .LT. 99, PASS DONE
0202 F800      306          LKI ZERO     ..RESET DAY COUNTER TO 0
0204 A6        307          PLO R6
0205 86        308 DONE:    GLO R6
0206 5E        309          STR RE
0207 C4        310          NOP
0208 C000F8    311          LBF MAIN     ..START NEW CYCLE
020B 00        312          IDL
020C           313          END
```

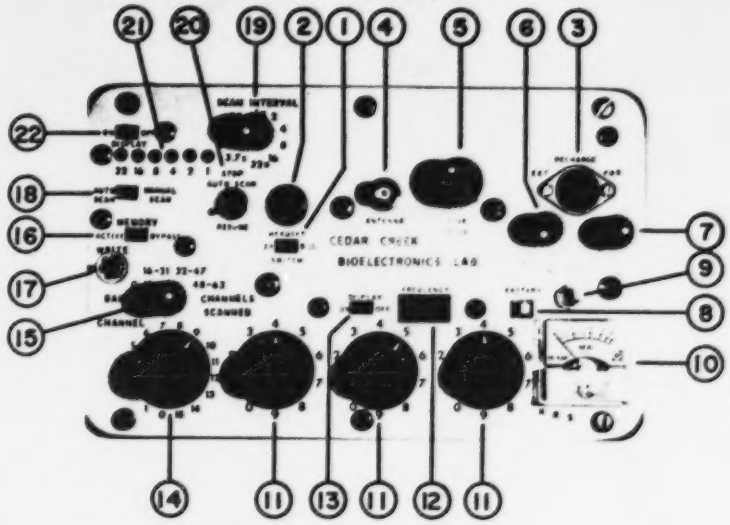
APPENDIX C

OPERATIONAL PROCEDURES FOR SYSTEM HARDWARE

I. Programmable scanning receiver

II. Microterminal note pad

This appendix describes the operating procedures for the memory equiped channel scanning receiver and microterminal note pad entry device for the Monticello Remote Sensing System (MRSS).



FRONT PANEL CONTROLS, CONNECTORS AND INDICATORS

(1) Headset Impedance Selector

(2) Headset Jack

(3) Battery Charge/External Power/Auxiliary Output

(4) Antenna Input Connector

(5) Fine Tune Control

(6) On/Off RF Gain Control

(7) Audio Gain Control

(8) Battery Status Indicator

(9) External 0-1 ma Recorder Jack

(10) Signal Level Meter

(11) Frequency Selector Switches

(12) Frequency Indicator

(13) Display On/Off Switch

(14) Memory Channel Selector

(15) Memory Bank Selector

(16) Memory Active/Bypass Selector

(17) Memory Write Switch

(18) Memory Auto/Manual Scan Selector

(19) Memory Scan Interval Control

(20) Stop Auto Scan Switch

(21) Auto Scan Channel Indicator

(22) Channel Display On/Off Switch

I. Programable Scanning Receiver

Function of Operator Controls

1. Headset Impedance Switch. This switch selects the best impedance match between the 2000 ohm telex headsets which are normally used and the 8 ohm Koss headsets which are used if ambient or wind noise is a problem.

2. Headset Jack. Provides receptacle for Headset or other listening device. Standard monouarl plug fits. Standard stereo plugs may be used if both head pieces are wired to the tip.

3. Battery Charge/External Power; Optional Input/Output. Provides receptacle for input power to recharge internal batteries and to provide power from external 12 volt power supply. Extra pins may also be used as optional input/outputs.

4. Antenna Input. Female BNC connector to provide for 50 ohm antenna input.

5. Fine tune. Allows shifting the 1st converter crystal frequency to provide fine tuning between the 1 kHz increments of the frequency synthesizer. It allows the operator to tune to the frequency that can be heard best or is the most comfortable.

6. On/Off - R.F. Gain. Turns power on and off from internal batteries or external power supply. The variable resistance control varies the R.F. gain in the input pre-amplifier to prevent signal overload on strong signals. This prevents spurious signals from being generated by intermodulation and cross modulation. R.F. gain is maximum when the control is fully clockwise.

7. Audio Gain. Controls the audio level in the headset. This control has very little effect on detectability of a signal. Maximum signal level is with the control fully clockwise.

8. Battery Status Indicator. Indicates voltage level of internal rechargeable batteries or external power source. It should be in the white area for proper operation.

9. 0-1 ma External Recorder. Allows insertion of an external meter in series with the internal meter to record signal strength on an external paper recorder.

10. Signal Strength Meter. Provides an integrated indication of the audio signal level.

11. Frequency Selectors. The three switches select which frequencies are to be passed through the receiver and which are blocked. Frequency can be selected in 1 kHz increments over a 1 MHz range. The 1 MHz range is determined by selection of the preamp and first converter.

Function of Operator Controls - Supplement - Memory Receiver

12. Frequency Indicator: Three digit display of the frequency. In the bypass mode the display will be the same as the frequency selector switches (11). When in the memory active mode it will display the frequency of the active channel.

13. Display on/off Switch: Turns off the display to save power when the display is not needed.

14. Memory Channel Selector: Sixteen position switch to address which channel is to be written or read into the frequency selector.

15. Memory Bank Selector: In 64 channel receivers the switch selects channels 0-15, 16-31, 32-47, or 48-63. 14 & 15 also control the number of channels scanned in the auto scan mode.

16. Memory Active/Bypass Selector: This switch determines whether the receiver frequency is selected by the memory (ACTIVE) or by the frequency selectors (11) on the front panel.

17. Memory Write Switch: This switch is used to transfer a frequency selected by front panel switches (11), into the memory channel selected by 14 & 15.

18. Memory Auto Manual Selector: Selects whether the memory is to be scanned by means of the channel selectors (14 & 15) or automatically by an internal timer.

19. Memory Scan Interval Control: Controls the rate of the internal timer for the auto scan mode. Intervals available are 3.75 sec., 7.5 sec., 15 sec., 30 sec., 1 minute, 2 min., 4 min., 8 min., 16 min., and 32 min.

20. Stop Scan Switch. Will stop the auto scan timer from advancing to the next channel until switch is returned to the resume position.

21. Auto Scan Channel Indicator: Lights indicate which channel is active in the auto scan mode. It is in binary code and can be converted to decimal by adding the number below the lights that are on.

22. Channel Display on/off Switch: Turns channel display LED's off.

Operating Procedure

Once the function of each control is understood, operating procedure follows quite easily.

(1)-(2) Headset Jack and Headset Impedance Switch:

The headset or other audio output device is plugged into the headset jack. The impedance switch is set to correspond to the impedance of the headset used; 8 ohms for the Koss or other stero types or 2 K for telex or similar 2000 ohm headsets. Headsets or audio devices of other impedance can be used with some loss in output level depending on the impedance mismatch and power required. For devices other than 8 or 2000 ohms the impedance switch should be set for the best output level.

(6) On/Off R.F. Gain. The on/off switch controls the power to all modules whether the receiver is operating on external batteries or is using an external power source.

The R.F. gain control should be rotated fully clockwise so the R.F. sections are operating at maximum gain to achieve maximum sensitivity. It should be left at maximum sensitivity until the transmitter or signal source can be heard. Once the signal is found, the gain should be reduced to achieve a signal level where differences in signal amplitudes can be easily detected. The gain should also be reduced as you move toward a signal source to prevent overload of the input stages. Although overload will cause no permanent damage to the receiver, it can cause spurious signals to be generated from cross or intermodulation. These spurious signals can cause confusion. Overload (spurious signals) can cause signals to appear on channel locations where no signal sources are

supposed to be. This problem usually does not occur during normal operation with perhaps two exceptions. 1) When attempting to determine whether a transmitter is working on the test bench. Extraneous signals may be detected while switching to the correct channel. Confusion may also result while attempting to check out a number of transmitters for test purposes. 2) Occasionally problems will be encountered while trying to move in on a signal source. These can almost always be cleared up by making sure the channel setting is correct for the signal source being searched and reducing the signal level. The setting of the R.F. gain control is probably the most critical for accurate and efficient signal source location.

(7) Audio Gain. The audio gain should be set for a comfortable noise level in the headset. Setting of the audio gain does not affect sensitivity except as effects hearing sensitivity. The audio level does not affect signal to noise ratio. It does affect the meter indication.

(3) & (8) Battery charge/external power; Battery level indicator. The battery level indicator should be in the white region when the receiver is turned on. If it is in the red region the internal battery voltage is low and in need of recharge or the voltage of the external power source is low. If an external power source is used, the receiver will switch automatically from internal to external power. The receiver is designed for a negative ground system. The positive supply line should be connected to pin 2 of the supply jack. If the polarities are reversed, a protective diode will block the current to prevent damage to the receiver. When external power is applied a audible click can be heard as the internal relay switches from internal to external power.

Caution. Be sure to turn the receiver off when the external power source is removed or the receiver will automatically switch to internal power and drain the batteries.

The internal NiCad batteries should be recharged approximately 1.5 hours for each 1 hour of use. The high level charges cannot be left on indefinitely without damage to the internal cells. If the charges are left on indefinitely, the internal batteries may rupture.

(9) & (10) Signal Meter/External Recorder. The meter gives an indication of the relative audio level in the headset. It can be used as an indicator in direction finding or as an indication of activity, if the activity behavior modifies the signal amplitude. It also integrates the signal level to make the meter less responsive to noise and to keep the meter needle from bouncing on pulsing transmitters. The meter level can be offset by an internal control adjustment.

The external recording jack allows connecting another 1 ma meter in series with the meter in the receiver for chart recording.

(11) & (5) Frequency Selectors/Fine Tune. These three selectors determine the frequency that will be received. They can be tuned in 1 kHz increments over a 1 MHz range. The mode of operation should be to tune to the frequency that you are interested in picking up to see whether a signal is present or not. It is virtually impossible to tune through the channels to find signals because of the high number of channels that would need to be scanned. The I.F. bandpass is at least 1.2 kHz wide so that any signal can be picked up within the 1 kHz increments.

It is important that the frequency of each transmitter be determined when the transmitter is placed on the animal so that it can readily be relocated later. In some cases it may be necessary to retune the least significant digit to compensate for frequency drift on the transmitter. Often the drift can also be compensated for by using the fine tune.

Memory Operating Instructions

Frequency selection switches (11) control the frequency to which the receiver is tuned with the active-bypass switch (16) in the bypass position. The receiver frequency will be displayed at (12) with the display switch (13) in the on position. The display draws approximately 40 ma or 1/3 of the current needed to operate the receiver. Power is saved with the display off.

The auto-manual scan switch (18) determines how the memory is addressed; by the channel switch (14) and bank switch (15), or the automatic scanning circuitry.

To program the memory, place the manual-auto scan switch (18) in the manual position. Set the channel (14) and bank (15) switches at the desired locations. Select the frequency desired with the frequency selector switches (11) and push the write switch (17) to the right. Change the channel switch to the next location and select the next desired frequency. Manually check the channels to be sure the desired frequencies have been programmed into the memory. To change a frequency on a given channel, address the channel, select desired frequency on selectors and push the write switch.

The channels will be scanned automatically with the auto-manual scan switch (18) in the auto position. The lights (21) indicate which channel the scanning circuitry is addressing when the channel display switch (22) is ON. The time the receiver will remain on a channel is controlled by (19). The intervals available range from 3.75 sec. to 32 minutes. The scanning circuitry scans sequentially. The scanner does not stop

scanning when the automanual switch is in the manual position, the memory, however, is addressed by the channel and bank switches.

The channel and bank switches (14 & 15) also control the number of channels scanned in the auto scan mode. If the channel switch is left at 7 and the bank switch at 0-15 the scanning circuitry will advance to channel 7 and return to 0.

The stop scan switch (20) will stop the scanning circuitry from advancing to the next channel. When the switch is returned to the resume position the next channel in the sequence will be addressed. This is useful when a signal is found when scanning for a number of frequencies. When a signal is heard you can stay on that channel as long as desired.

The memory is kept alive when the receiver is off by a small internal power source. This power source should last at least one year.

System Hardware

The RCA COSMAC Microterminal CDP18S021 consists of keyboard and display unit, its connecting cable and mating connector, and a ROM containing a Utility Program (UT5) to run the terminal and various subroutines that user programs can access. Although initially designed for use with the COSMAC Evaluation Kit CDP18S020, the Microterminal can also be used with comparable user-designed hardware support systems. The following descriptive material provides the information necessary to interface the Microterminal to the Evaluation Kit or to an appropriate system.

Keyboard/Display Unit

A photograph of the Microterminal is given in Fig. 1 and a block diagram of the keyboard/display unit in Fig. 2. The Microterminal system is divided into three functional sections: control, display, and keyboard.

The control section contains the requisite hardware for controlling the operation of the microprocessor system. The function keys are as follows:

R	Reset: resets the logic of the Microterminal and microprocessor system. Puts the CDP1802 in Reset state.
RU	Run Utility: starts execution of the Utility Program (UT5), which is at location 8000.

RP	Run Program: starts program execution at location 0000 with R0 as program counter.
CONT/STEP	Slide switch to enable continuous or single-step operation of the microprocessor system.
↔	Entry Mode Control: this key toggles between the address entry and data entry modes.
INC	Increment Address: each depression increments the address shown in the display. In the data entry mode, it also causes the data byte shown to be written to the address shown before incrementing the address.
$P	Start Addressed Program: starts program execution at the location shown in the address display.
CA	Clear Address: clears (resets) the address display to 0000.

The R, RU, RP, and CONT/STEP controls perform the same functions as the corresponding switches on the Evaluation Kit. For users designing their own systems, the execution of these control functions can be seen in the Evaluation Kit Manual for the RCA CDP1802 COSMAC Microprocessor, MPM-203.

The keyboard section of the Microterminal contains 16 digit keys (0 through F) that are used to enter hexadecimal numbers into the address or data field. The destination of entered data is controlled by the ↔ mode toggling switch. The hexadecimal digit keys and some of the control function keys are encoded and sent to the microprocessor system on the bidirectional data bus, as shown in the logic diagram of Fig. 3. Logic is provided for scanning and signalling keyboard activity to the microprocessor. The actual scanning, debounce, and decoding algorithms are performed by software routines in the Utility Program.

The display section consists of an eight-digit seven-segment LED display, display drivers, and refresh logic. In either the data entry or address entry mode of operation, the display shows a four-digit address field on the left side and a two-digit data field on the right separated by blank positions. In other subroutine-oriented display modes, all eight-digits are available in two groups of four separated by blank positions. This subject is discussed further in the section, System Software. Illuminated decimal points in either the address or data field indicate the current operating mode. Software routines in the Utility Program perform digit selection, multiplexing, and hexadecimal-to-seven-segment code conversion.

Keyboard Operation

Depression of any key (except R, RU, or RP) produces a signal on EF3 of the CDP1802 as shown in Fig. 3. This signal starts the Utility Program which then issues an input instruction 6C to bring in the encoded data. This data is compared with a code table to discern which key was depressed. As shown in Fig. 3, the keys are in three groups.

Fig. 1 - RCA COSMAC Microterminal CDP18S021.

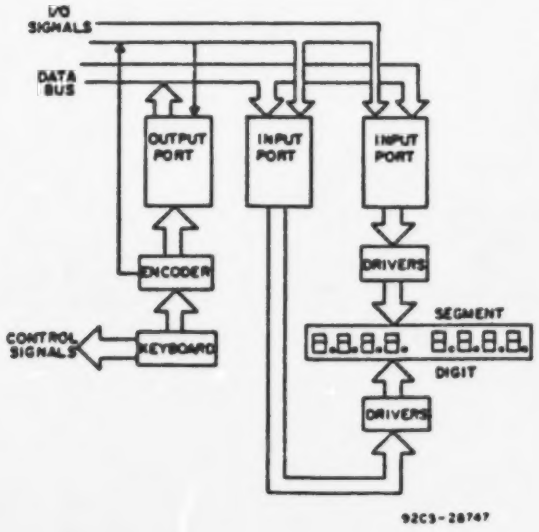


Fig. 2 - Block diagram of COSMAC Microterminal keyboard and display unit.

Coding is produced by Exclusive-Or gates which invert certain bits depending on key group. To eliminate key "bounce", a debouncing routine repeatedly scans the input until consecutive valid codes are found. Subroutines to scan, decode, and debounce keys are given in the UT5 listing, Appendix B.

Display Operation

Each LED is composed of seven-segments and a decimal point. The eight LED's are connected to eight-segment drivers which in turn, are driven by an output port (U6). Output instruction 63 is used to latch segment data into this port. A second output port (U5) is used to turn on the selected digit with output instruction 64 used to latch the digit selection information. Multiplexing and segment control are provided by subroutines in UT5.

Digit and segment codes are shown in Fig. 4. To display a character, the respective codes for the segments of the character are fetched and the result sent to output port #3. The appropriate digit code is then sent to output port #4 to complete the operation.

A separate 5-volt supply V_{LED} is provided for the LED's and their drivers. The rest of the logic is supplied from V_{CC}, which may range from 5 to 12 volts. It should, of course, be the same voltage and from the same supply as the interfacing signals to the microprocessor system.

Utility ROM

The Utility ROM contains the software routines required to interface the Microterminal to a microprocessor system. These programs are collectively known as UT5. The ROM is a mask-programmed CDP1832D device, branded CDPR522, with a 512 x 8 configuration. UT5 is programmed to occupy memory locations 8000 through 81FF. It requires 32 bytes of RAM starting at location 8C00 for a stack area. For user-designed microprocessor systems, a CDP1824D RAM at location 8C00 will fulfill UT5 stack requirements. Standard COSMAC hardware support systems already have such a RAM.

There are two main sections in UT5: the KEYUT routine which handles the terminal interface, and user-oriented subroutines. These functions are described in the section, System Software.

APPENDIX D

EFFECTS OF RADIO TRANSMITTERS ON THE WHITE SUCKER

INTRODUCTION

Effects of radio transmitters on fish can potentially introduce uncontrolled variables to a behavioral study, therefore, it is important to optimize tagging methods in order to minimize bias. Three experiments were conducted to evaluate the impact of various radio transmitter applications with the white sucker (Catostomus commersoni). White suckers were selected as a test species due to the EPA's interest in this fish as an indicator organism for toxicological experiments and because previous work indicated that small suckers readily adapted to the shallow slow moving water at the Monticello E.R.S. Due to the poor survival of white suckers in our experiments, additional limited testing was conducted with walleye (Stizostedion vitreum), northern pike (Esox lucius) and smallmouth bass (Micropterus dolomicui). The objective of the white sucker studies was to observe growth and survival of fish tagged with internal and external dummy radio transmitters.

METHODS

Three types of transmitter application have been developed for use with fish; external attachment, in stomach and surgical implant (Stasko and Pincock, 1977). We selected the external attachment described by Winter et al. (1978) and surgical implant procedures used by Hart and Summerfelt (1975), and Johnson and Hasler, (1977). External antennas were implanted with the method proposed by Winter et al. (1978) and a modification of this method. Stomach implants were not considered for this study due to regurgitation problems (Kelso 1976) and because we

needed an external antenna. Emphasis was given to surgical implants due to the abundant aquatic vegetation present in the Monticello experimental channels.

In general the experimental design consisted of contrasting survival and mortality among several treatment groups of white suckers. Dummy radio tags were constructed to simulate size weight and negative buoyancy of actual radio transmitters. Sham tagged fish were taken through the entire tagging procedure but the dummy tag was not applied. The first experiment contrasted a gut cavity surgical implant with an external dorsal mount, sham tagged fish and untagged controls. Each treatment group contained 30 individuals. Test fish were tagged on Nov. 12, 1977 and released into an experimental channel. Survivors were recovered on Dec. 1, 1977 and Feb. 18, 1978 by electro fishing, and on April 19, 1978 by draining the channel.

A second similar experiment commenced on May 19, 1978. This test included additional treatment groups of internal transmitters placed posterior to the pelvic girdle (reverse internal) and surgical implants with varying antenna lengths. Again each treatment group contained 30 individuals. Groups were evenly divided between two experimental channels; 135 fish per channel. The experimental channels were monitored intermittantly for mortalities. Additionally the channels were electrofished and seined once a month to observe surviving fish. On Oct. 12, 1978 the channels were drained and all surviving fish recovered.

A third bioeffects experiment was conducted in laboratory tanks to observe the cause of radio tagged white sucker mortality and to determine if refinements in surgical technique might facilitate further work with

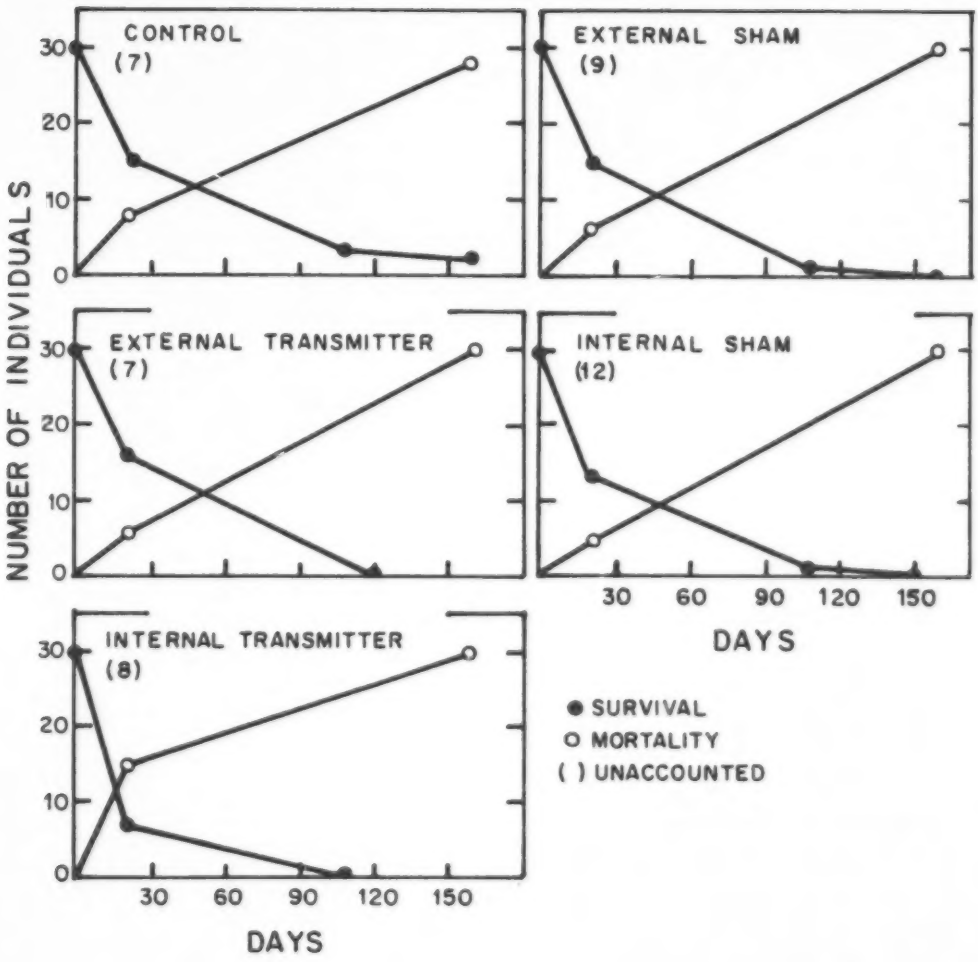
this species. This test consisted of tagging 12 white suckers with the surgical implant method proposed by Winter et al. (1978), utilizing a tunneling tool to place the whip antenna between skin and muscle tissues along the linea alba. A second group of 12 white suckers was tagged with a modified surgical implant technique. The modification consisted of using a half-curved veteranary needle shielded with plastic tubing to route the antenna along the outside of the intestine as opposed to tunneling between tissue layers (Ross and Kleiner, 1982). The major advantages of this modification were that it permitted the transmitter to be placed proximal to the pelvic girdle away from vital organs and the incision. Also this modification avoided the trauma associated with forcing a needle between skin and muscle tissue. Twelve white suckers were held untreated as control fish. The test was run for 11 weeks.

Additional bioeffects observations were made on white suckers, walleyes, northern pike and smallmouth bass when fish were released with functional radio tags to check out deveopmental versions of the radio tracking system. Transmitters were implanted in these fish with the tunnel method during July and August, 1978 and with the shielded veteranary needle technique during September and October, 1978. MS-222 anaesthetic concentrations were varied with the white sucker in an attempt to determine if dosage was responsible for the high amount of mortality.

RESULTS

The initial experiment during the 1977-78 winter months resulted in substantial white sucker mortality in all treatment groups within 20 days after tagging (Fig. 1). Highest mortality had occurred in the internal

Figure 1. Winter 1977-78 bioeffects: Five treatments with dummy radio transmitters, 30 white suckers per treatment group.

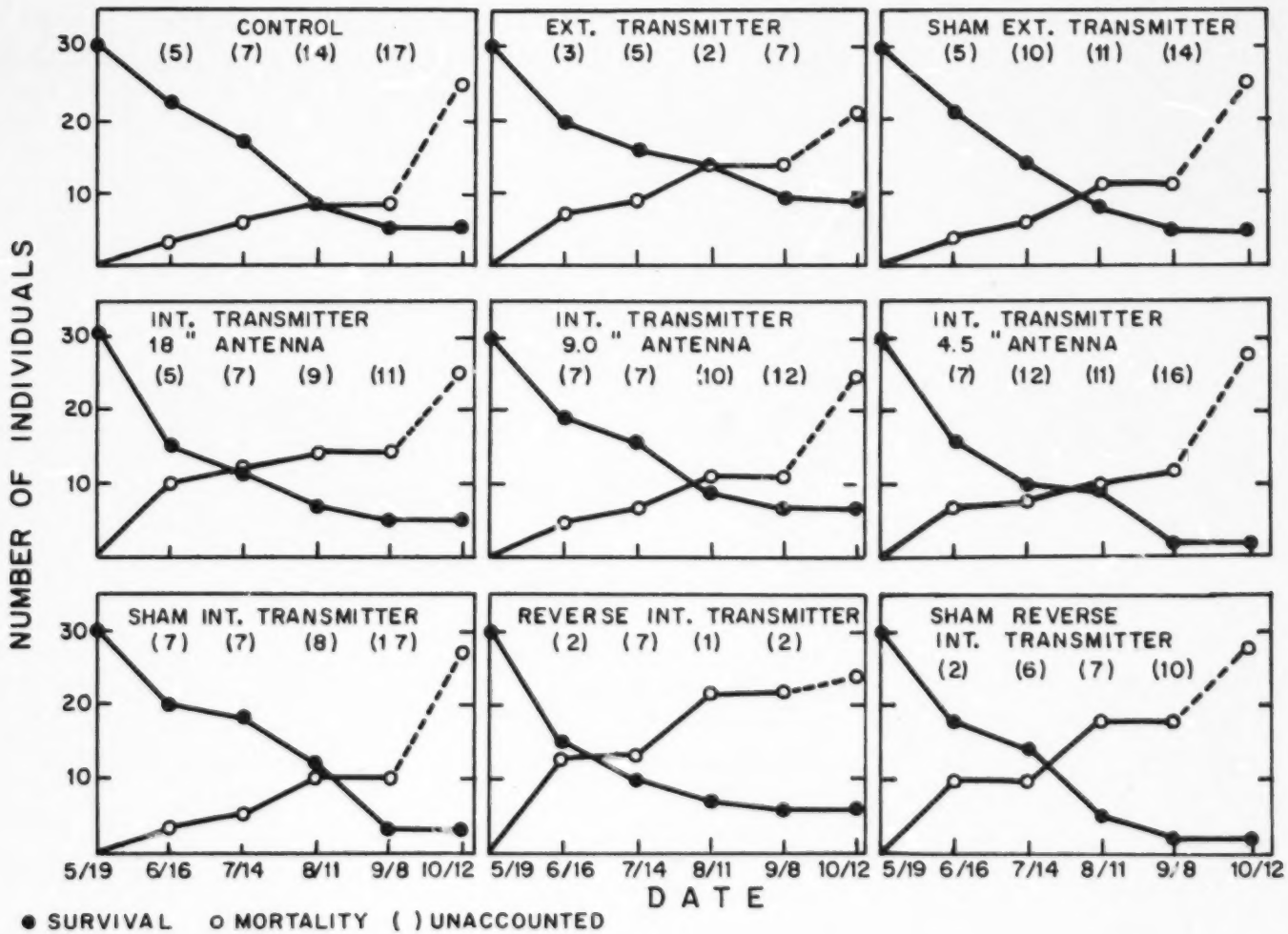

CONTROL
(7)
EXTERNAL SHAM
(9)
EXTERNAL TRANSMITTER
(7)
INTERNAL SHAM
(12)
INTERNAL TRANSMITTER
(8)
NUMBER OF INDIVIDUALS
0
10
20
30
30
60
90
120
150
DAYS
● SURVIVAL
O MORTALITY
( ) UNACCOUNTED

transmitter group (50%) contrasted to 27% in the control fish. Mortality in other treatment groups varied from 17% to 20%. When the channel was drained on April 17, 150 days after tagging, only 2 controls were found alive.

A second expanded bioeffects experiment during the summer months of 1978 also resulted in substantial mortality in all treatment groups. Fig. 2 indicates that survivorship was best in the external transmitter group but even this group had suffered 70% mortality by October 12, 146 days after tagging. The dashed line on the right side of the mortality curves in Fig. 2 merely indicates that most 'unaccounted' fish during the electrofishing and seining samples were mortalities. This was confirmed on October 12 when the channels were drained and previously 'unaccounted' fish were either found dead or missing. Missing fish were presumed to have died prior to being consumed by snapping turtles, mink, muskrats and avian predators.

Observations on tagged fish during the summer sampling periods indicated that, among surviving fish, sutures had virtually healed by July 15, (57 days after tagging), with the exception of the reverse internal transmitter groups. Fish in the reverse internal groups had incisions posterior to the pelvic girdle. Incisions between the pelvic girdle and anus along the linea alba did not heal properly, sutures tore through the flesh and transmitters dropped out. These problems were likely due to the carangiform swimming motion of the white sucker where the posterior regions of the fish flex considerably more than the anterior regions. Thus, the constant movement of the area posterior to the pelvic girdle precluded proper healing of sutured incisions.

Figure 2. Summer 1978 bioeffects: Nine treatments with dummy radio transmitters, 30 white suckers per treatment group.


CONTROL
(5) (7) (14) (17)
EXT. TRANSMITTER
(3) (5) (2) (7)
SHAM EXT. TRANSMITTER
(5) (10) (11) (14)
INT. TRANSMITTER
18 " ANTENNA
(5) (7) (9) (11)
INT. TRANSMITTER
9.0 " ANTENNA
(7) (7) (10) (12)
INT. TRANSMITTER
4.5 " ANTENNA
(7) (12) (11) (16)
SHAM INT. TRANSMITTER
(7) (7) (8) (17)
REVERSE INT. TRANSMITTER
(2) (7) (1) (2)
SHAM REVERSE
INT. TRANSMITTER
(2) (6) (7) (10)
NUMBER OF INDIVIDUALS
30
20
10
5/19 6/16 7/14 8/11 9/8 10/12
DATE
● SURVIVAL o MORTALITY ( ) UNACCOUNTED

External transmitters tended to loosen considerably over the 146 day test period resulting in abrasion to the underlying tissue. The stiff twist-o-flex antenna on external transmitters caused chaffing on the upper lobe of the caudle fin even though the wire was shielded with teflon tubing. Internal transmitters with short antennas (11 cm) terminating within 2 cm of the exit hole tended to irritate the antenna exit incision. In some cases these transmitters shifted enough in the body cavity so that the antenna no longer protruded. Internal transmitters with 22 cm and 44 cm flexible 26 ga. teflon covered conductor wire antennas did not appear to have any adverse effects at the antenna exit incision.

Results of the third bioeffects experiment carried out in laboratory tanks are presented in table 1. Six of 12 suckers tagged with the 'tunneling' method died compared to 5 tagged with the modified method and 2 control fish. Internal and incision hemorrhaging was identified as the cause of death in 5 out of 6 'tunnel method' mortalities and 2 of 5 'modified method' mortalities. The remaining mortalities died of a combination of fungus and unidentified causes. One control fish died of a fungus like infection on both gills, the other control mortality had severe abrasions and hemorhaging on the snout region.

In July and August, 1978, 52 white suckers were equipped with functioning radio transmitters to test the prototype tracking system. All transmitters were surgical implants in the gut cavity with 22 cm antennas. Mortality in this group of white suckers was virtually total within 2 to 4 weeks after release.

During September and October 1978 an additional 29 white suckers, 12

Table 1. Radio tagged white sucker survival and mortality in the laboratory tank study.

	Survived	Died				
Control	10	2				
Tunnel Method	6	6				
Modified Method	7	5				
		Cause of Death				
	Internal Hemorrhage	Incision Hemorrhage	Internal Infection	Fungus	Other	Unidentified
Control				1	1	
Tunnel Method	4	1				1
Modified Method	2		1	1		1

northern pike, 5 smallmouth bass, 4 walleyes and 1 red horse (Moxostoma sp.) were equipped with functioning radio transmitters to test tracking system compatibility with thermally and pH altered experimental channels located away from the main antenna cable. Eight white suckers, 4 walleye, 2 smallmouth bass and 2 nothern pike all with surgical implants and eleven white suckers with external transmitters, were released on September 5, 1978 into a thermally altered channel. All the white suckers died within 2 weeks. All of the remaining fish survived except one walleye. On October 17 and 19, 10 northern pike, 10 white suckers, 3 smallmouth bass and 1 redhorse with surgical implants were released into a pH altered channel. Only 7 nothern pike survived this test.

SUMMARY

Bioeffects experiments with white suckers indicate substantial problems with applying existing radio telemetry methods to this species. Additionally, high mortality rates of non-tagged control fish in experimental channels implies that the relatively restricted, shallow, and highly productive experiment may not be suited for studies with larger adult white suckers. All experimental fish had to be transported to the Monticello E.R.L. prior to tagging and release into a new environment. This compound trauma likely contributed substantially to the high mortality rates encountered in the white sucker.

Attempts to modify and improve tagging and surgery techniques included varying anaesthetic doses, closely monitoring temperature and aerating anaesthetic, surgery and recovery bath solutions. The shielded upholstery needle techique appeared to be less traumatic to the fish and reduced internal hemoraging compared to the tunnel method. However,

these changes and modifications did not significantly improve white sucker survival.

While experiments were not specifically designed to observe tagging effects on other species it was apparent that the walleye and northern pike adapted more readily to the tagging process and experimental channels when compared to white suckers. Even though the walleye and northern pike were exposed to thermally and pH altered environments these species exhibited better survival than the white sucker.

REFERENCES

Hart, L.E. and R.C. Summerfelt. 1975. Surgical procedures for implanting Ultrasonic transmitters into flathead catfish (Pylodictis olivaris). Trans. Am. Fish. Soc. 104(1):56-59.

Johnson, P.B. and A.D. Hasler. 1977. Winter Aggegations of Carp (Cyprinus carpio) as revealed by ultrasonic tracking. Trans. Am. Fish. Soc. 106(6):556-559.

Kelso, J.R.M. 1976. Movement of yellow perch and white sucker (Catostomus commersoni) in a nearshore Great Lakes habitat subject to a thermal discharge. J. Fish. Res. Bd. Canada 33:42-53.

Ross, M.J. and C.F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio frequency transmitters in fish. Prog. Fish. Cult. 44(1):41-43.

Stasko, A., Bond, D.G. Pincock. 1977. Review of underwater biotelemetry, with emphasis on ultrasonic techniques. J. Fish. Res. Board Canada 34(9):1261-1285.

Winter, J.D., V.B. Kuechle, D.B. Siniff and J.R. Tester. 1978. Equipment and methods for radio tracking freshwater fish. Univ. of Minn. Inst. of Ag. Misc. Rep. 152. 45 p.